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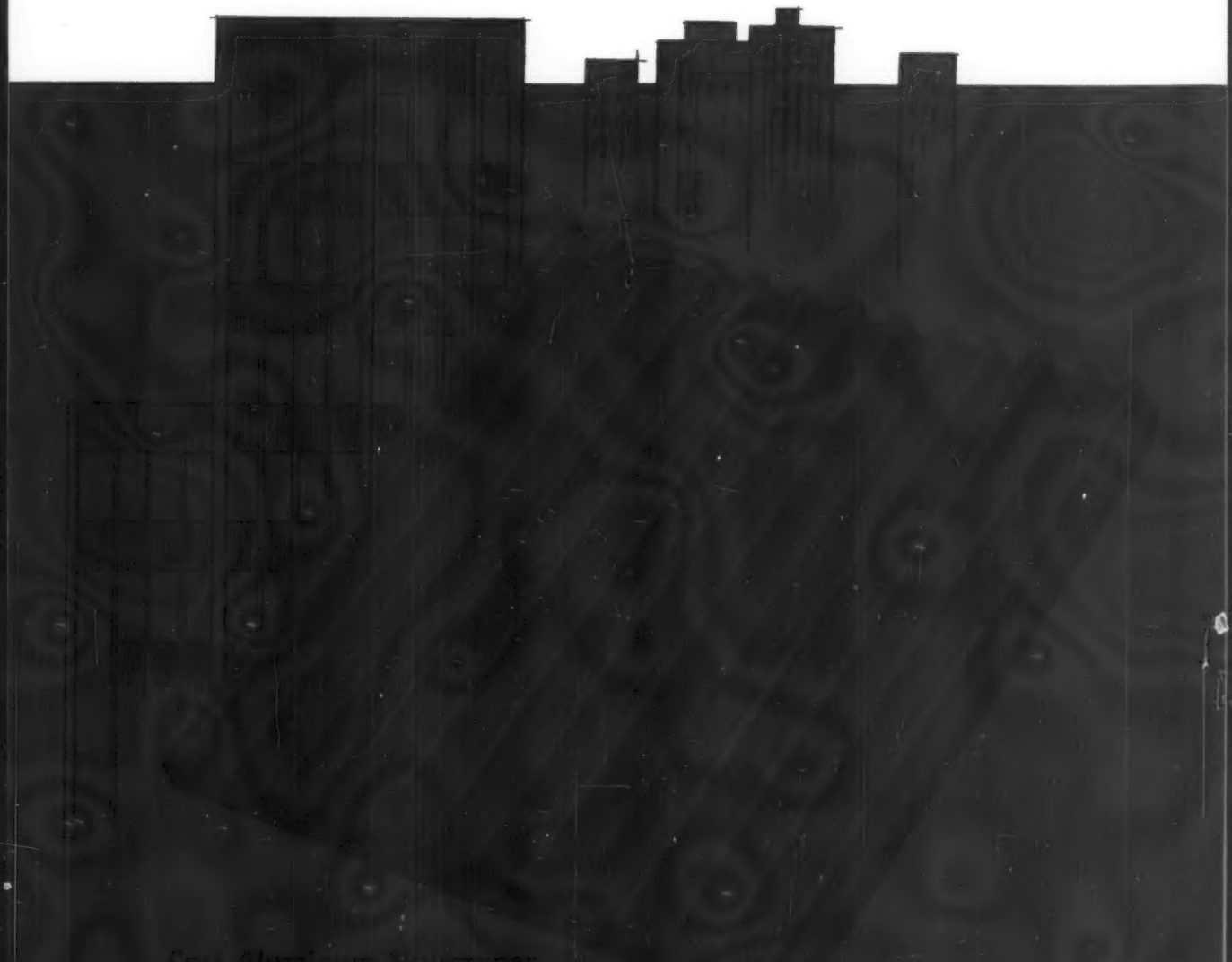

Cast Aluminum Skyscraper
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modern castings

DECEMBER 1960

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December 1960 Vol. 38, No. 6

modern castings

metalcasting "technology-for-profit"

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GENERAL MANAGER
WM. W. MALONEY

Let's look at . . .

PROFITS FOR YOU!

H. E. Green

THERE ARE SOME timely editorial innovations in MODERN CASTINGS this month which are important to you as readers. Each new change is keyed to *technology-for-profit*. Each is part of our up-to-date approach to your needs and problems. Let's examine these:

First, you will find "Looking at Business" on page 7. This is designed to spotlight and interpret current business trends and opinions. We recognize the close community of interests *(technology-for-profit)* of metalcasters today—top management, middle management, technicians—and seek to give expert guidance.

Second, in our main news stories you will find a new and timely, interpretative emphasis. This is to keep you right on top of business trends as they begin to emerge. This fresh, vital coverage is a tribute to the talents of our editors and news correspondents. It reflects enterprise and real know-how.

Third, because of the greatly increased interest in MODERN CASTINGS, as a result of its *technology-for-profit* approach, Editor Jack Schaum has initiated "The Editor's Forum." This establishes an even closer contact between MODERN CASTINGS and its readers. You'll find this on page 162.

Significantly, these changes and innovations in MODERN CASTINGS are coming in response to your demonstrated interests and desires. We do this uniquely. And we apply the techniques necessary for a superior metalcasting magazine today: management and technological know-how, modern journalistic thinking and techniques, editorial exclusiveness, reader need, editorial enterprise, and industrial leadership. We are also pleased to announce the appointment of four geographical contributing Editors (see page 125). Each of these men is well known in the metalcasting industry and can be expected to make important editorial contributions to its progress.

We are serving you and the metalcasting industry in all of its profit-making aspects. Our goal is to produce profits for you through technology.

Harold E. Green

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Looking at Business with Modern Castings

NATIONAL SCENE

The economy related to the national election looks something like this: businessmen are now less cautious in their outlook for 1961. There's more optimism, for inventories are lower and trimming has gone about as far as it can go in many segments of metalcasting.

The president-elect did not get a mandate to push radical inflationary measures. He barely "squeeked" by. Consequently the new Congress will tend to be more conservative than the last one. Before the election there were economy stimulators underway: increased defense orders, speeded-up highway construction, eased credit restrictions. It looks as though the administration will be doing quite a bit of horsetrading. Thus metalcasters and suppliers to the industry can plan marketing programs with more confidence.

REGIONAL CONDITIONS

Business in various key regions of the U. S. and Canada currently is "comme ci, comme ca". In British Columbia, for example, business is down a little; in New England, gray iron foundries are up and down, depending on the industries served. In the Mid-west, activities are down 25 to 35 per cent, with an upturn expected to come gradually. According to one spokesman for a foundry supplier in the Mid-west, metalcasters themselves, in the main, control the future of the industry. The complete report starts on page 126, this issue.

FERROUS SHIPMENTS

Gray iron castings shipped in August totalled 858,503 thousand short tons. This is seven per cent above the previous month's shipments and 16 per cent over August, 1959.

Malleable iron castings shipped in August totalled 58,785 thousand short tons, or 18 per cent above July shipments. However, the August figure is 10 per cent below the previous August.

August shipments of steel castings jumped to 101,709 thousand short tons from the previous month's total of 89,565. This is four per cent higher than the total for August 1959.

NON-FERROUS SHIPMENTS

Latest reports indicate that a total of 63,765 thousand pounds of copper and copper-base castings were shipped in August this year, which is 15,366 thousand pounds more than was shipped in July.

Aluminum and aluminum-base castings shipments in August were also up over July. August totalled 58,647 thousand pounds compared with 45,694 thousand pounds in July.

Zinc and zinc-base alloy castings shipped in August totalled 45,056, a jump over July of 9,939 thousand pounds.

Magnesium and magnesium-base alloy castings shipped in August totalled 2,025 thousand pounds, compared with July's total of 1,638 thousand pounds.

NEW BUSINESS

Grumman Aircraft Engineering Corp., Bethpage, N. Y., has received a Navy contract ($37.7 million) to build additional car-

rier-based S2F-3 Tracker anti-submarine planes. They are powered by two Curtis-Wright R-1820 engines.

New orders received by American Brake Shoe Company, New York City, for the third quarter this year totalled $34,100,000. The late Fall backlog of orders stood at $35,600,000.

Net income of American Steel Foundries increased nine per cent, and sales climbed seven per cent, according to the fiscal year-end report. ASF's earnings for the year were the third largest in the company's history, exceeded only in 1956 and '57. Income for 1960 totalled $7,793,363 and sales were $120,-141,812, compared with $7,168,027 and $112,311,287, respectively, in 1959.

TECHNOLOGY-BUSINESS

Any ductile iron shop that does not develop markets for this product is passing up some lucrative business, according to J. H. Kimes, Jr., Tenn-Texas Alloy & Chemical Corp. Ductile iron is a natural replacement for steel weldments and forgings for it has very good castability and gives physical properties that are better than the steel used in weldments and forgings, Kimes says. Also it can be designed and cast to give much better appearance than weldments, and eliminates the high cost of forging dies. He told members of the Texas chapter of AFS that ductile iron castings can be sold in small quantities, whereas forging dies are too costly for small production runs.

He reported Texas shops have been busy making ductile iron castings for oil well equipment, idler arm for automotive steering systems, gears and rack, saddle horns, assorted farm equipment parts, truck air conditioner brackets, assorted wrenches, brake brackets, pumping unit component, brake and clutch levers, cam levers, clutch housing, radiator mounts, etc.

Kimes stated that local Texas shops are producing castings which are better than average. Seems as though this results from greater experimental work than is being done in shops in other regions of the country. A roundup of the Texas meeting is given on page 139.

CONSTRUCTION

Engineering and construction projects by Koppers Co. are expected to maintain a relatively high level in the last quarter of 1960. Several large construction projects are currently under consideration which, it is hoped, will materialize before the end of the year. Fred C. Foy, chairman and president reports his company anticipates "a reasonable degree of prosperous business activity".

A 5 per cent rise in housing starts is predicted next year, by Robert W. Lear, director of marketing, American Radiator and Standard Sanitary Corp. He anticipates both public and private new home construction will rise to between 1,350,000 and 1,400,-000 units. (The estimate by National Gypsum Company's Vice President of Marketing, Wade Hildinger is 1,200,000). Lear further predicts that private construction volume will approach $40 billion. It will start slow during the first quarter of next year, but gain momentum, thereafter. Non-residential construction, he predicts, will continue strong during most of 1961.

Bethlehem Steel, low bidder for building four cargo ships, has been awarded the contract for $34.1 million. The vessels will be built at the firm's Sparrows Point, Md. Yard, and are the fourth group of ships for which contracts have been let in a replacement program of Lykes Bros. Steamship Co.

Circle No. 162, pages 157-158 ←→

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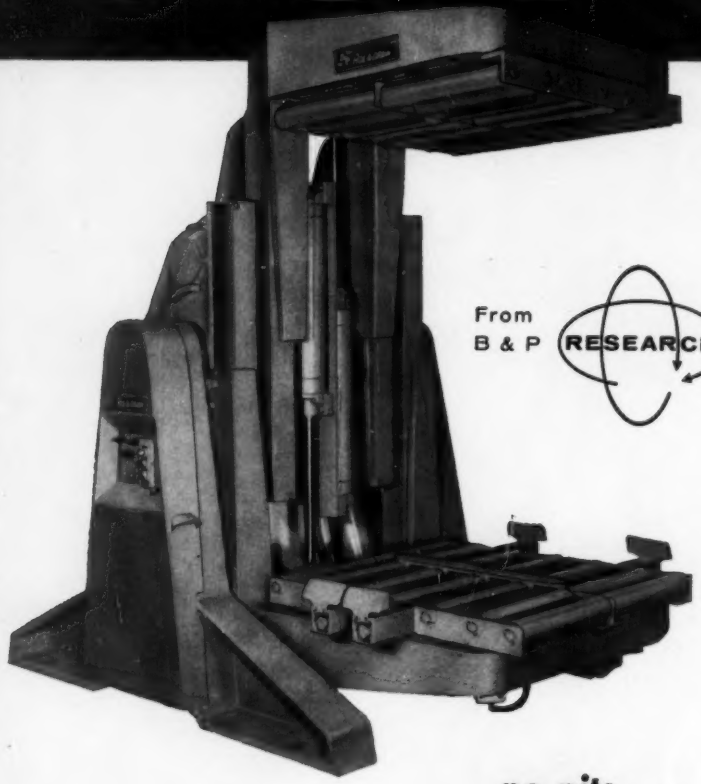

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MEMBER FEMA

Around the World with Modern Castings

UNITED STATES

A number of U. S. corporations are planning to supply their foreign markets by creating or expanding overseas production facilities. This move takes advantage of cheaper labor, lower overhead, tariff regulations, and exchange controls. The industries involved produce automobiles, tractors, farm implements, and machine tools—all big users of castings. Naturally these castings will be purchased in the country where the end products are produced. This move is aimed at making the parent companies more competitive in the world market places. But it will be a real blow to our domestic labor force and the multitude of suppliers involved in these important manufactured products. U. S. foundries are bound to be hurt in this shuffle.

Foreign governments are taking a strong initiative in encouraging this movement. Belgium's Prince Albert recently came to the United States to personally encourage our industries to build in his country. Northern Ireland has offered to lend American businessmen, at low interest rates, up to 33 per cent of cost of new plants or rent ready-made factories at low rentals. It looks like the attitude of many business men faced with tough overseas competition is: "If you can't beat 'em, join them."

RUSSIA

Russian steel casting production was double that of U. S. in 1959! According to a statement made by the Russian delegation to the International Committee of the Technical Foundry Associations, 3,000,000 tons of steel castings and 13,000,000 tons of gray iron castings were produced in 1959. This compares with 1,400,000 tons of steel castings and 12,300,000 tons of gray iron in U. S. for 1959. Reliable sources say this output is destined to continue to grow at a rapid rate.

ENGLAND

To break faulty or worn-out castings, particularly large ones, into pieces convenient for disposal or for study, several firms have just started using explosives very successfully. Reports from the research and development departments of Council of British Cast Iron Research Association point up the necessary charges are very much smaller than those required for equivalent sections of steel. Also the cost may be less than other methods. However, there is the dangerous aspect which must be considered, and proper provisions made which conform to regulations.

UNITED STATES

Manufacturers in metalcasting are much concerned about foreign competition. This was obvious at the recent annual meeting, Foundry Equipment Manufacturers Association.

Attention centered on State Department influence and the tariff and

← Circle No. 163, pages 157-158

trade restrictions imposed by other countries. It was pointed out that American dollars spent in foreign countries are not coming back. To compound matters, there is a greatly increased flow of competitive finished and semi-finished products into the United States.

Significantly, U. S. manufacturers are looking with more interest at overseas franchising agreements and setting up foreign subsidiaries.

Reporting on his recent tour of European countries (including the International Foundry Congress in Zurich, Switzerland) William W. Maloney, general manager, American Foundrymen's Society, said that:

1. Greater emphasis is being placed on research and technological development.
2. Competition is getting keener among metalcasters and suppliers.

He emphasized that there are good opportunities for equipment licensing in Europe for American manufacturers.

Topping the examination of competitive factors here and abroad at FEMA was Dexter M. Keezer, a leading industrial economist. He pointed out that the foundry industry has a tremendous amount of obsolete equipment. Replacement of this would spark much beneficial sales activity. He also stressed that research and technological developments will be the key to profits in 1961.

BULGARIA

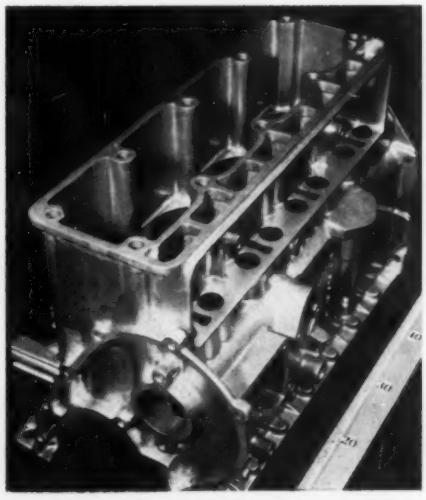
Latest reports indicate that an exothermic mixture of aluminum, ferrous oxide and saltpeter is being used near the tapping hole where it is ignited by the molten metal as it pours into the molds. This combustion prevents "dead metal" from forming inasmuch as the metal is kept at a high temperature. Loss due to "dead metal" has been reduced by as much as 25 per cent at Stalin Engineering works. And annual saving is estimated at about $351,000.

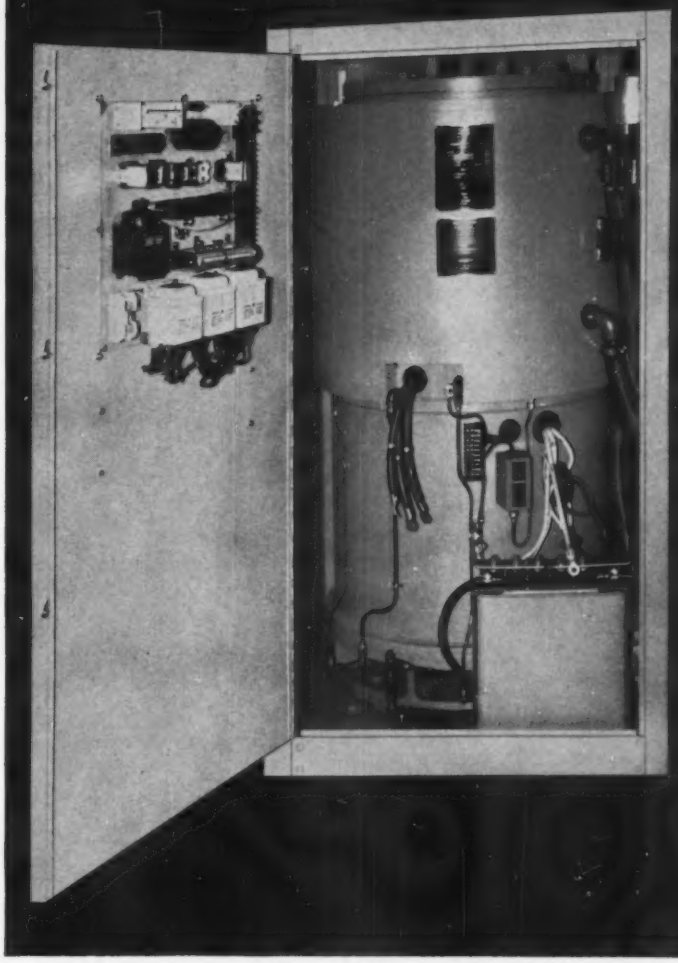
CHINA

Pig iron production has increased 13 times in 11 years at the Shichingshan Works, near Peking. This has been during the reign of the "peoples government." And reputedly, the plant is currently one of the country's major iron and steel producing units, having grown from a small foundry. Reconstruction and expansion is continuing very swiftly according to latest information to filter out of the country.

ITALY

One problem facing die casters around-the-world seems to have been solved. A. Triulzi has built and made operational a 2500 ton die casting machine for making the complex 2500 cc aluminum cylinder block shown on the right—net weight 42 pounds (51 pounds gross weight with sprues). The machine is integrated with a melting furnace, automatic degassing, ladling, and ejection, and a die trimming press. European leadership in compact car production hinges on their advanced fabricating techniques including die casting.





- FORCED OIL LUBRICATION of the upper and lower bearings gives twice the normal expected bearing life.
- ALL AUXILIARY COMPONENTS are safely contained and mounted within the heavy gauge steel enclosure.
- EASY ACCESS for servicing or inspection without disassembly of cabinet or shroud.
- SINGLE OVERSIZED AREA water to air heat exchanger provides cooling.
- SPECIAL ROTOR LOCKING DEVICE prevents brinelling of bearings during shipment.
- FULL COMPLEMENT OF PROTECTIVE DEVICES including an annunciator panel.

The AM Motor Generator Unit is a proven Vertical Design with new features to improve service life and maintenance.

WATCH AM

FOR THE NEW IDEAS IN THE HEATING AND MELTING OF METALS BY INDUCTION

HIGH FREQUENCY MOTOR GENERATOR SETS

Another of the many products of AM for the heating and melting of metals by induction.

"induction heating is our only business"

Ajax Magnethermic CORPORATION

GENERAL OFFICES
P. O. BOX 839
Youngstown 1, Ohio

TRENTON DIVISION
930 Lower Ferry Road
Trenton 5, New Jersey

YOUNGSTOWN DIVISION
3990 Simon Road
Youngstown 1, Ohio

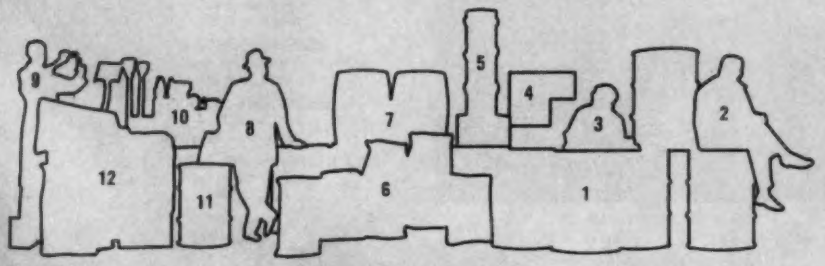
AJAX MAGNETHERMIC, CANADA, LTD.
BOX 778
Ajax, Ontario

Circle No. 164, pages 157-158

KEY TO ADM PRODUCTS & SERVICES:

Check the products or services on which you would like to have more information. Then clip out this KEY, attach it to your letterhead, and mail to

Archer-Daniels-Midland company
FEDERAL FOUNDRY SUPPLY DIVISION
2191 West 110th Street, Cleveland 2, Ohio



1. BINDERS FOR EVERY CORE PROCESS: Featuring CHEM-REZ A-200, the chemically-reactive binder that "bakes" at room temperature; CHEM-REZ "100", with hot box curing, makes intricate cores at high production rates; LIN-O-SET, ADM's air-setting binder; ADCOSIL, for CO_2 gas-cured cores; ADMIREZ foundry resin for shell molds and cores; LINOIL and INDUCTOL, industry's most reliable oils for quality baked-sand cores.

2. TECHNICAL FIELD SERVICE is an ADM extra that puts a qualified foundry engineer into your plant when you need him most.

3. FAST ORDER SERVICE: Prompt attention to handling and shipping your orders from a nationwide network of plants and warehouses is the constant aim of ADM.

4. TECHNICAL INFORMATION on all ADM products is available upon request.

5. SAMPLE SERVICE: New ADM products and special formulations can be furnished for trial batches in your foundry.

6. PRODUCTS FOR CONTROLLED CASTING QUALITY: GREEN BOND BENTONITE for maximum mold bonding strength with minimum moisture; CROWN HILL SEA COAL for consistent control of casting surface finish and dimensional stability; LIN-O-CEL and FEDERAL SAND STABILIZERS prevent thermal flaws in casting surfaces.

7. PARTINGS: ADM manufactures a full line of powdered and liquid partings: FEDERAL NON-SILICA PARTINGS assure clean lifts; ADM ZIP-SLIP is ideal for baked sand cores, oil or resin bonded. FREFLO gives 30 to 50 draws from a single application.

8. SALES SERVICE within easy reach. There's an ADM-MAN in your area ready to aid your foundry in the production of better cores and molds at less cost.

9. RESEARCH & DEVELOPMENT: ADM laboratories are dedicated to the development of new products and faster techniques to improve casting quality, speed production, and reduce costs. Services of the ADM laboratories are available to customers in the analysis of their special production problems.

10. SPECIAL FOUNDRY PRODUCTS, SUPPLIES & EQUIPMENT: SHOVELS, FLASKS, RUBBER PIEN SHOVEL HANDLES, PASTE BULBS, PITT-COR fiberglass core reinforcement, SPRAY CANS and over 200 other supplies are stocked in 50 warehouses ready for immediate shipment. If you need it, ADM carries it.

11. CORE PASTES: Several varieties available to answer your specific pasting needs on small or large cores of any composition, hot or cold.

12. WASHES & BLACKINGS: ADM offers a wide variety of refractory washes for spraying, swabbing, brushing or dipping. Among the types: Plumbago, Zircon, Ceramic, Graphitic, to assure smooth, clean, pattern-true casting finishes.

Ease the profit squeeze

with a PAYLOADER®

Brighton Electric Steel Casting Company reports the H-25 "PAYLOADER" improves operations several ways:

1. Provides more efficient mechanized handling for several different jobs.
2. Operates fast and effectively in close quarters.
3. Operator efficiency sustained during the full shift because of easy operation.
4. Maintenance is low in spite of hard usage.

Brighton Electric Steel Casting Company, Beaver Falls, Pa., makes piercer points for the seamless steel tubing industry, and has earned a fine reputation for uniform high quality and precision workmanship in this specialized field. Its decision to acquire a Model H-25 "PAYLOADER" has proved to be a wise one. This tractor-shovel has brought new efficiencies to their overall operation since it took over several sand-handling and castings-handling duties.

Efficient and Reliable. Foundry Foreman, Thomas Gillingham, says, "The H-25 'PAYLOADER' has many features that definitely increase foundry efficiency. One of these is close-area maneuverability. The operators claim ease of operation with accurate control of material load. It has rugged construction that stands up continuously under rough working conditions with simple maintenance."

Superior Mechanical Features. Speed, capacity, maneuverability and ease of operation are combined in the H-25 for big production all day long — thanks to 2,500-lb. operating capacity, power-shift transmission, torque converter drive, power-steering, power-transfer differential and fast, powerful hydraulic bucket control.

A Size for Every Job. For any bulk-handling job, indoors or outdoors, there is a *proven* "PAYLOADER" — up to 12,000 lbs. operating capacity. A nearby Hough Distributor is ready to show you how a "PAYLOADER" can "ease the profit squeeze". Return the coupon, or write:

HOUGH®

THE FRANK G. HOUGH CO.
711 SUNNYSIDE AVENUE
LIBERTYVILLE, ILLINOIS
SUBSIDIARY — INTERNATIONAL HARVESTER COMPANY

Send "Industrial Materials Handling the PAYLOADER way"

Name _____
Title _____
Company _____
Street _____
City _____
State _____

11-G-2

Circle No. 152, pages 157-158

Reader Opinions and Ideas . . .

WHAT'S IN A WORD?

Thank you for your letter and for the complimentary copies of MODERN CASTINGS, Sept. 1960. The tear sheets which you so kindly forwarded have been received. It would be much appreciated if, say, two dozen more tear sheets could be sent as the present supply was exhausted immediately within our own staff.

There is one point, however, I must bring to your attention. The statement on page 42, "mammoth cores weighing as much as 44,800 lbs harden quickly in place at Strathclyde Foundry." is not correct. One core does not weigh that much. Instead, this should be, the main cores (total weight 20 tons—44,800 lbs.) four being necessary for the first part of the casting, and three of total weight 15 tons (33,600 lbs) are required for the second part of the casting.

Editor's Note: Our apologies. We certainly did not intentionally publish a misleading statement. Guess we just got carried away with all that weight, and didn't weigh our words as carefully as we should have.

WANTS OPERATION ARTICLE

Your issue of July 1960 is extremely interesting, and my management is particularly interested in utilizing facts in your article "How to make money in the Foundry business".

As I am loath to cut this article from my issue, which I am binding, I would appreciate it if you could send me tear sheets of this article.

N. J. MODY
Bombay Metal & Alloys
Mfg. Co. Private Ltd.
Bombay, India

Editor's Note: We are always pleased to provide extra tear sheets of MODERN CASTINGS' *articles. This one is on its way to you.*

DATA ON ADDING BISMUTH

We wonder if you have any information on the addition of bismuth to iron in foundry operations.

We are investigating one such situation. We find appreciable amounts of bismuth fume, but have not yet completed our analysis for boron. The workers compain of eye and throat

BALANCE AND COMBINED STRENGTH

. . . you get the best of both in BLACK HILLS BENTONITE

There's no tug-of-war among important Black Hills Bentonite characteristics at the expense of other necessary traits. You get high strength plus a well-balanced blend of better bond clay qualities.

Take resilience for example — a sand's degree of yield or give before breaking (deformation). Black Hills excels over any other type of bond clay in this vital characteristic. It's really tough! Result: less trouble with difficult lifts . . . less breakage of corners and edge molds.

You get high green strength and high hot strength, too. Used as directed, it also gives you high permeability with a minimum amount of tempering water. There's less material to handle, less dead clay left to be removed, less work in the long run.

And you get highest dry strength — added insurance against cuts and washes, particularly in steel foundry practice.

For unbiased and cost-free recommendations on Black Hills Bentonite, or any other bond clay in IMC's complete product line, get in touch with our service engineer who calls on you, or write direct.

EASTERN CLAY PRODUCTS

INTERNATIONAL MINERALS & CHEMICAL CORPORATION

ADMINISTRATIVE CENTER, OLD ORCHARD ROAD, SKOKIE, ILLINOIS, YORKTOWN 6-3000

IMC

PRODUCTS FOR GROWTH*

*TRADEMARK

Circle No. 153, pages 157-158

for precision castings

PETRO BOND*

ABCO ALUMINUM & BRASS WORKS, Houston, Texas, finds that PETRO BOND molding sands meet all requirements for precision castings. Pictured here is an aluminum dry air heater coil cast in PETRO BOND sand.

ABCO Aluminum & Brass Works, Houston, Texas, uses PETRO BOND as the sand-bonding agent for all precision castings. ABCO has found that PETRO BOND molding sands consistently produce fine-finish castings. The smooth surfaces reduce finishing costs... tolerances are closer... there are fewer rejects.

PETRO BOND sands are bonded with oil instead of water. This permits the use of fine-grain sands with less gas. Molds shake out fast, sand doesn't stick to castings.

PETRO BOND produces better castings with conventional foundry equipment. Castings are smoother . . . with less porosity because of better riser feeding . . . pattern reproduction is more faithful.

PETRO BOND is available from foundry dealers everywhere. See opposite page for list of dealers.

BAROID

BAROID CHEMICALS, INC.

*Registered Trademark, National Lead Company

6061

Circle No. 160, pages 157-158

irritation. Whether this is due to bismuth, boric acid, or gases arising from the core resins, we do not know.

Any information on this problem and the seriousness of the probable exposure would be appreciated.

HERVEY B. ELKINS, Director
Division of Occupational Hygiene
Department of Labor and Industries
Commonwealth of Massachusetts

Note: The solubility of boron in alpha iron is 0.15 per cent at 1679 F. and decreases with decreasing temperature.

At room temperature the tertiary iron-boron solid solution transforms into two solid solutions of FeB and Fe_3CFe_2B.

In practice, ferro-boron is added to the furnace or crucible and since so little boron is retained in the iron, boric oxide is given off which may convert to boric acid under certain conditions.

No irritation occurs from the bismuth or boric oxide fumes, as far as my experience teaches me. The irritation is due, in my opinion, to vapors from core resins and oils when the metal is poured in the mold—not during inoculation.

Central Foundry Div., General Motors Corp. has patented Armasteel which is made by inoculation of iron with bismuth and boron. In fact, they are the largest producers of the alloy.

No ill effects from bismuth-boron have been reported in our industry. But to confirm this, why not contact General Motors. HERBERT J. WEBER, Director, AFS Safety, Hygiene and Air Pollution Control Program.

REPRINTS ON GRAY IRON

We were very much impressed by the article "Gray Iron Vs. Aluminum" by C. A. Sanders in the June MODERN CASTINGS. We would like to obtain additional copies if possible.

ROGER N. HABERMAN
Grede Foundries, Inc.
Milwaukee

Editor's Note: Reprints of this article may be obtained at nominal cost from American Colloid Co., Skokie, Ill.

CITES AFS BENEFITS

I am writing in appreciation of the service rendered to Mainland Foundry by Herb Weber on his recent speaking engagement in Vancouver.

In our foundry we have all air hoists and they were certainly noisy. A small tip by Herb Weber on a very inexpensive and simple muffler has reduced the noise by at least 75%.

In my opinion, this is another proof that attending meetings and supporting the AFS can offer benefits which are almost invaluable to a foundry such as ours.

H. Heaton, Plant Supt.
Mainland Foundry Co. Ltd.
Vancouver, B. C.

HELP IS APPRECIATED

I am delighted at your willingness to review and offer your most valued comments on the Russian "Handbook for the Foundry Worker."

As a result of your comments, I feel I can assure you that OTS will publish this work. I will keep you advised, and send you review copies when it is published.

Again, let me express my personal appreciation and that of the entire OTS organization for your generous and helpful cooperation.

James E. Wheat, Jr., Chief
Publications & Public
Information Division
U. S. Dept. of Commerce
Washington, D. C.

Editor's Note: Foundrymen casting aluminum and magnesium should watch for this book, which will be a compendium of light metal casting practices. To date, I have not seen anything published in this country that is nearly so complete as this extensive Russian treatise.

DATA ON HOT CORE BOX

In Modern Castings, October 1960, you have an article on page 7 about the Renault Works in France having developed a hot core box method for producing cores.

We are presently working with our vendor foundries in order to obtain a better quality casting. I have been assigned the project of working with resin binders.

Any information that you can give me on the Renault resin binders and any other material regarding this subject, will be greatly appreciated.

James F. Tetzlaff
GMC Detroit Diesel Engine Div.
Detroit, Mich.

Editor's Note: Description in British Cast Iron Research Journal, July, 1960.

REPRINTS FOR SUPERVISORS

May we have 50 copies, if available, of the story in the November Modern Castings, titled, "Seven ways to Solve Steel Castings' Slow

Continued on page 22

smoother surfaces with

PETRO BOND*

ABCO ALUMINUM & BRASS WORKS, Houston, Texas, cast this heater coil from manganese bronze, using PETRO BOND sand. Note the smooth surface, the faithful pattern reproduction, the absence of porosity.

These dealers stock PETRO BOND

American Steel and Supply Company, Chicago, Illinois
Asbury Graphite Mills, Inc. Asbury, New Jersey
Asher-Moore Company, Richmond, Virginia
Brandt Equipment and Supply Company, Houston, Texas
George W. Bryant Core Sands, Inc., McConnellsville, New York
The Buckeye Products Company, Cincinnati, Ohio
Canadian Foundry Supplies & Equipment Ltd., Montreal 30, Quebec (Main Office)
Canadian Foundry Supplies & Equipment Ltd., Toronto 14, Ontario
Combined Supply & Equipment Company, Buffalo, New York
Foundries Materials Company, Coldwater, Michigan
Foundries Materials Company, Detroit, Michigan
Foundry Service Company, Birmingham, Alabama
General Refractories Company, Indianapolis, Indiana
The Hoffman Foundry Supply Co., Cleveland, Ohio
Independent Foundry Supply Company, Los Angeles, California
Industrial & Foundry Supply Company, Oakland, California
Interstate Supply and Equipment Co., Milwaukee, Wisconsin
Klein-Farris Company, Inc., Boston, Massachusetts
La Grande Industrial Supply Co., Portland, Oregon
Marthens Company, Moline, Illinois
Carl F. Miller and Company, Inc., Seattle, Washington
John P. Meninger, Elwood Park, Illinois
Pennsylvanian Foundry Supply & Sand Co., Philadelphia, Pennsylvania
Robbins and Behr, Chattanooga, Tennessee
Smith-Sharpe Company, Minneapolis, Minnesota
Steelman Sales Company Munster, Indiana
Warner R. Thompson Company, Detroit, Michigan
Western Materials Company, Chicago, Illinois
Walter A. Zeis, Webster Groves, Missouri

Write today for BOOKLET giving further information on the benefits gained from using PETRO BOND.

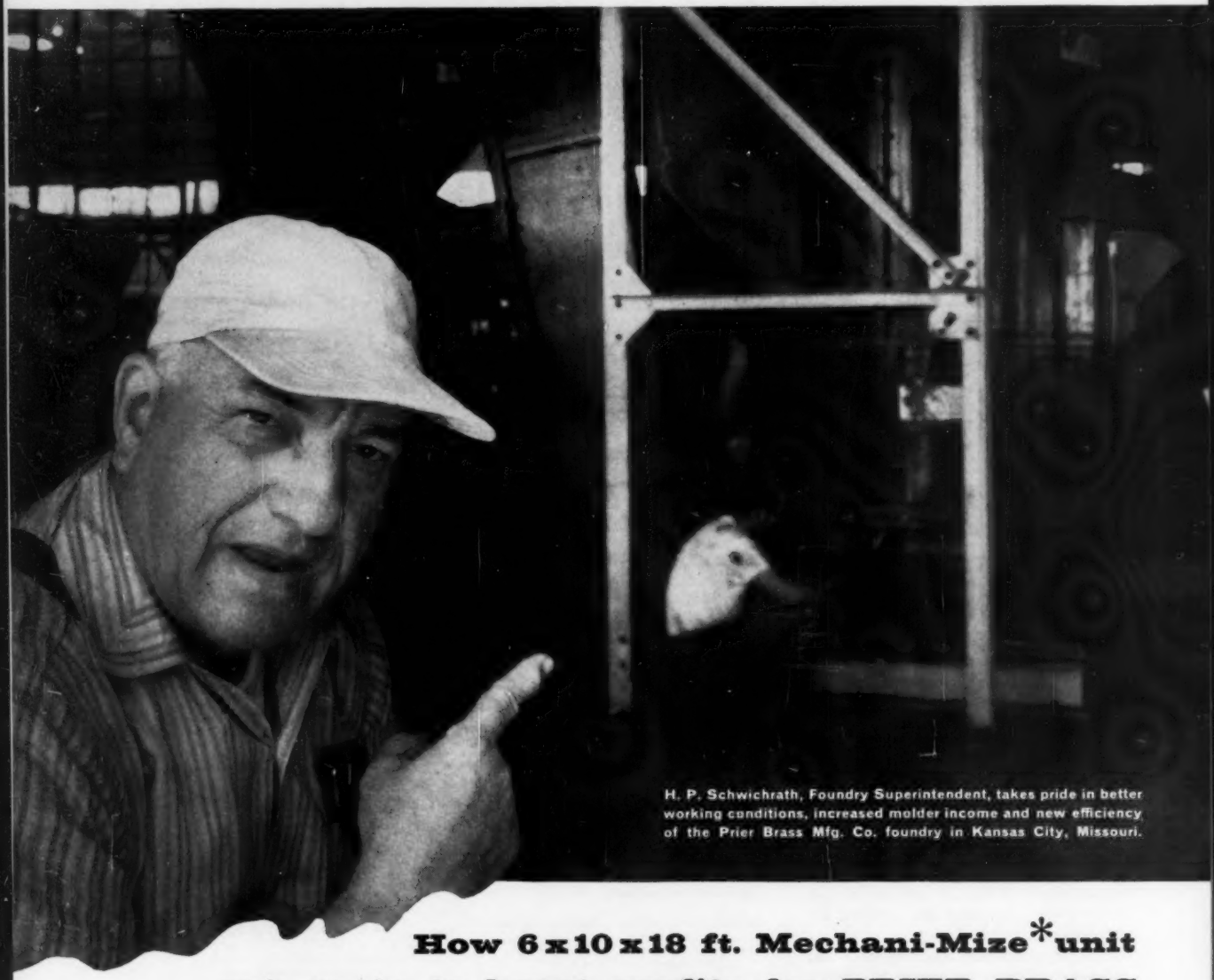
BAROID

6062

BAROID CHEMICALS, INC.
A SUBSIDIARY OF NATIONAL LEAD COMPANY
1809 SOUTH COAST LIFE BLDG., HOUSTON 2, TEXAS

Circle No. 160, pages 157-158

"This MIX-MULLER installation has



H. P. Schwichrath, Foundry Superintendent, takes pride in better working conditions, increased molder income and new efficiency of the Prier Brass Mfg. Co. foundry in Kansas City, Missouri.

How 6 x 10 x 18 ft. Mechani-Mize* unit cut waste to boost profits for PRIER BRASS

"Before we installed our Simpson Mechani-Mize system, we were dumping whole hopper loads of prepared sand and scrapping 'leakers' (pressure tested valves) by the score.

"With the automated Simpson system, I calculate our output is up about 15%. Molders are turning out more molds a day . . . and earning more income by doing it. Scrap is at a new low with improved casting finish as an added bonus . . . thanks to automated moisture and batch control we don't waste sand . . . we're holding green strength steady at 10.2 and permeability at 18.0.

"Only minor system changes were needed to switch over to the Mix-Muller Mechani-Mize unit . . . and National handled the whole thing in only 6 x 10 ft. of floor area."

This is what Mr. H. P. Schwichrath has to say after one year of operating with a 1½F Simpson Mix-Muller and National Elevayor in this medium size, specialty brass foundry. His comments add up to profits for Prier Brass.

Mechani-Mize made sense to progressive foundrymen like Mr. Schwichrath and John Marshall, Prier Brass Plant Engineer . . . because National showed them how they could cut costs and produce more and *better* castings without major change to their existing set-up.

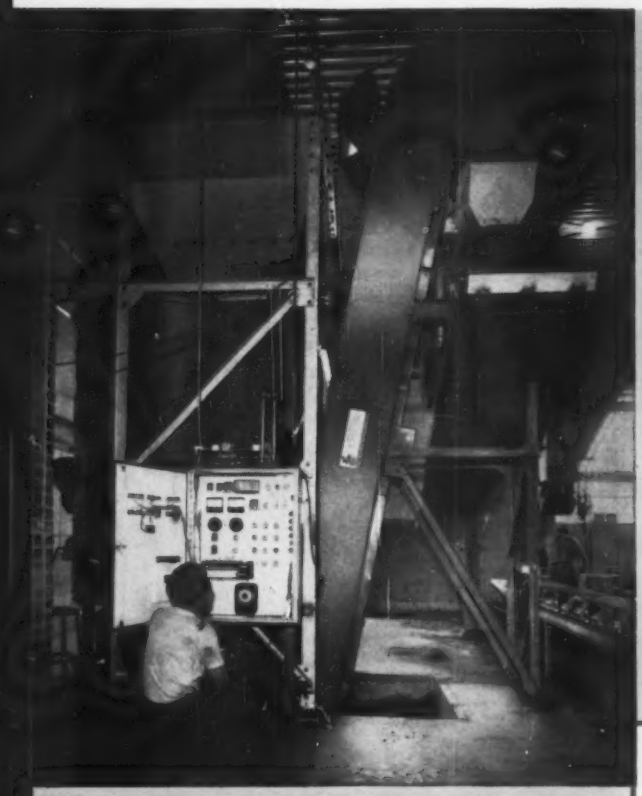
We can do the same for most any foundry caught in the bind between mounting costs and diminished profits—it will pay you to ask your National agent for more information about the benefits of *Mechani-Mize.*

**Meaning . . . now it's easy and economical to get your sand up off the floor without major plant changes or big equipment investment.*

NATIONAL ENGINEERING COMPANY

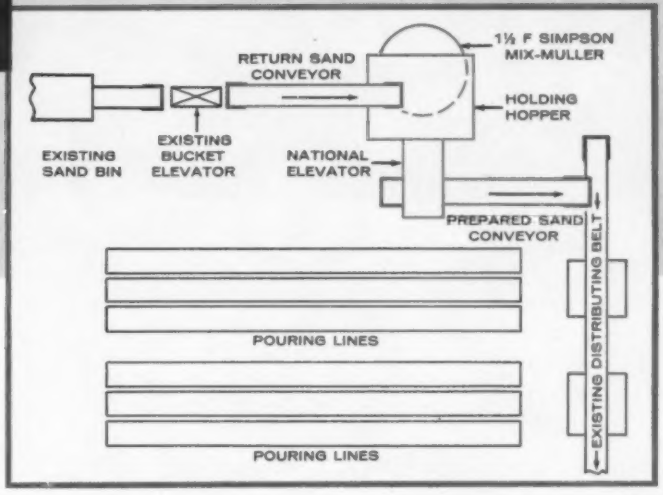
Circle No. 148, pages 157-158

increased our production by 15%"



At Prier Brass, 1000 lb. batch is prepared every 1 min. 45 sec. in this 1½F Mix-Muller. Unit is charged by automated batch control system. Moisture is controlled by automatic injection device.

Elevayor returns sand to distributing belt via cross belt. Note chutes used to accumulate spill sand at central point.



Sketch of Prier Brass layout points up compactness of National **Mechani-Mize** preparing plant. All layouts, engineering, erection and start-up were handled by National.

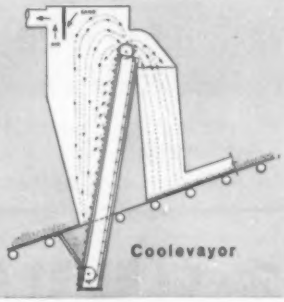
P980

MECHANI-MIZE
Foundry-wise

. . . with National unitized equipment specifically designed to help you get sand up off the floor without major plant change or big equipment investment.

Screen Master

Molder's Helper



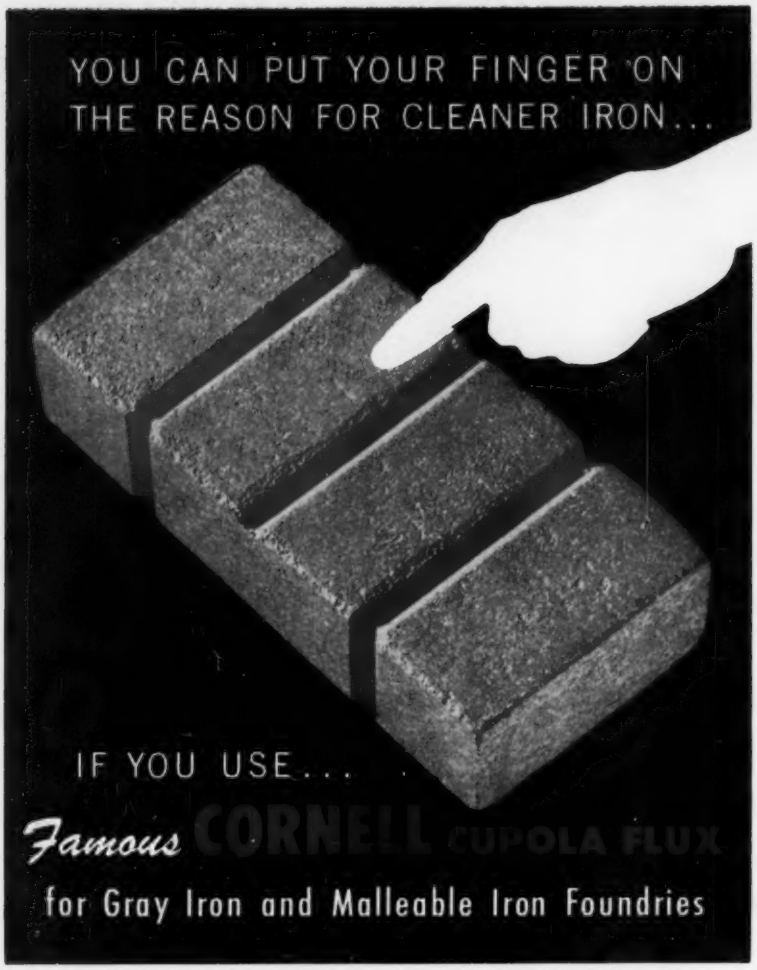
Coolevayor

SIMPSON MIX-MULLER®

646 Machinery Hall Bldg. • Chicago 6, Illinois

In Canada: 17 Queen St., East, Toronto 1, Ontario

Circle No. 148, pages 157-158


YOU CAN PUT YOUR FINGER ON
THE REASON FOR CLEANER IRON...
IF YOU USE...
Famous CORNELL CUPOLA FLUX
for Gray Iron and Malleable Iron Foundries

There are certain chemicals, when combined, that make a good fluidizer. Famous Cornell Cupola Flux has these special chemicals which purify molten metal and thus make cleaner iron. But don't take our word for it. Give Famous Cornell Cupola Flux a 30-day trial and see for yourself. You'll soon join us in saying there is no better fluidizer made on this earth—or any other.

P.S. Have you tried Famous CORNELL Aluminum, Brass or Copper Flux?

They're the right answer to proper Aluminum, Copper and Brass melting . . . Write for Bulletin 46-A.

don't accept substitutes

FAMOUS CORNELL LUXES

The CLEVELAND FLUX Company

1026-40 MAIN AVENUE, N.W. • CLEVELAND 13, OHIO

Manufacturers of Iron, Semi-Steel, Malleable, Brass, Bronze, Aluminum and Ladle Fluxes—Since 1918

Circle No. 159, pages 157-158

Continued from page 18

Growth Problem?" I think all of our salesmen and top supervisors should have copies for their attention.

L. E. Young, Sales Manager
Superior Steel &
Malleable Castings Co.
Benton Harbor, Mich.

Editor's Note: We are pleased that the article has drawn much favorable comment from within the steel foundry industry.

WANTS CASTING CHART

I should like very much to obtain some additional copies of the Casting Quality Chart which was published in a recent issue of MODERN CASTINGS.

Will you kindly sent me five copies of the chart?

G. A. FISHER, Chief Metallurgist
National Malleable &
Steel Castings Co.
Phoenix, Ariz.

Would you kindly send us three more copies of the Casting Quality Chart contained in your last October 1960 issue?

This is a chart developed by the Harry W. Dietert Company and was adapted by MODERN CASTINGS. We would like to have one for each of out testing laboratories and offer you our thanks as well as congratulate the Harry W. Dietert Company on developing this chart.

CLYDE A. SANDERS,
Vice President, Sales
American Colloid Co.
Skokie, Ill.

Editors Note: Glad to be of service to you. Anyone else wanting extra copies for use in foundry operations, please see item on page 159.

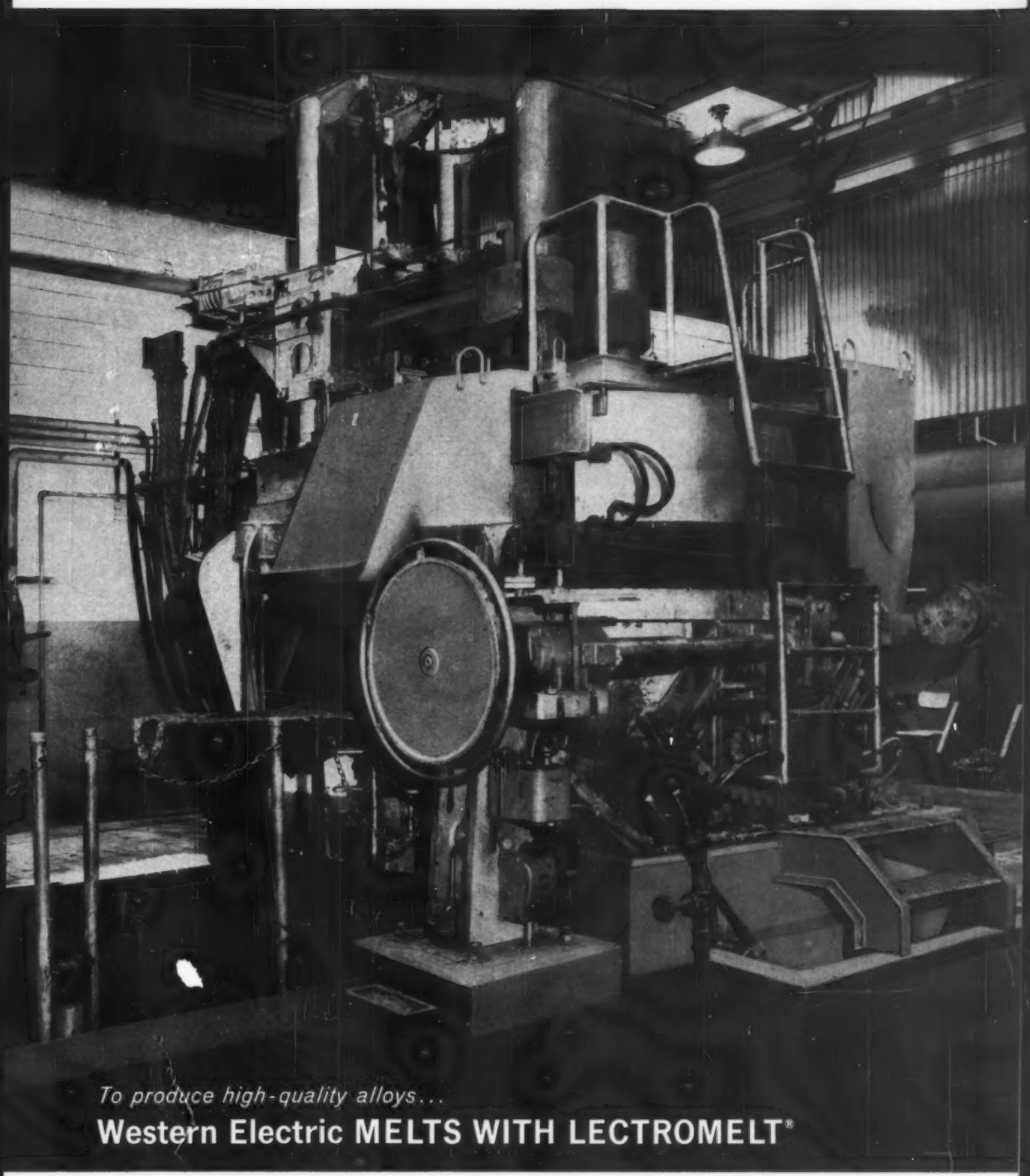
WANTS REPRINTS

We were very pleased to read the article entitled "Squeeze the Safety Factor, Allow Less for Ignorance" which appeared on pages 44-46 in the November, 1960 issue of MODERN CASTINGS.

We are interested in obtaining reprints of this article. Please send me a quotation for the cost of 1500 reprints.

I also noted the excellent run-down of yours: "New Market Opportunities for Steel Foundries". Yes sir!! They haven't scratched the surface.

Franklin S. Catlin, Manager
Marketing Development
Magnaflux Corp.
Chicago, Ill.



To produce high-quality alloys...

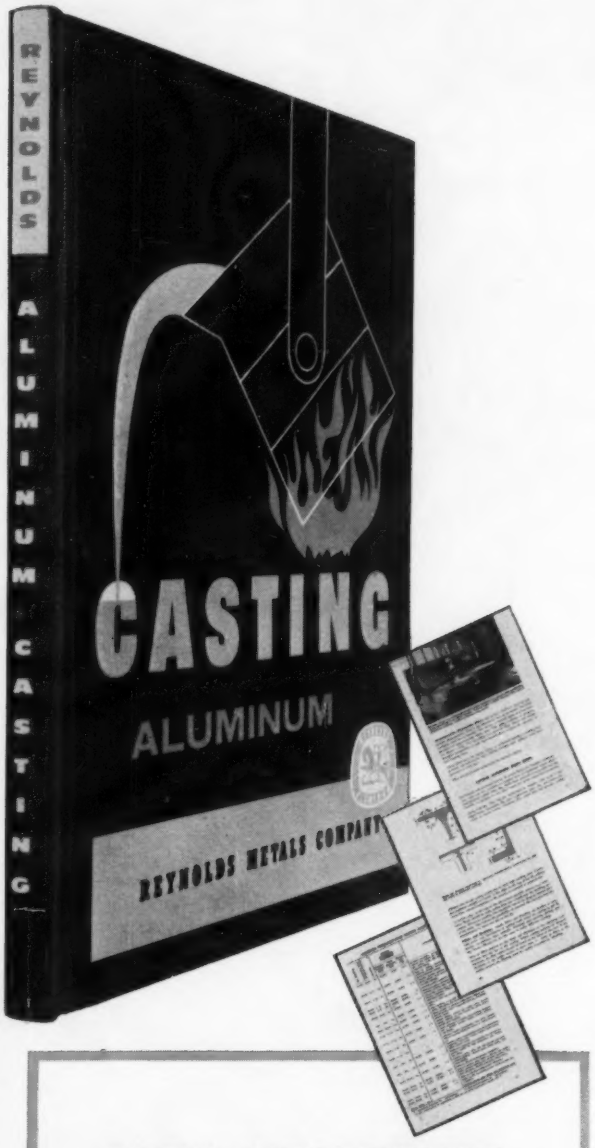
Western Electric MELTS WITH LECTROMELT®

To produce Permalloy® and other high-quality cobalt-nickel alloys, Western Electric Company Incorporated has among its installations a Lectromelt "PT" furnace at its Hawthorne plant in Chicago. This 9-foot furnace makes 7-ton heats with the high degree of uniformity Western Electric must have for its exacting needs. Dependable Lectromelt Furnaces – with such features as fast top charging ...accurate control...rapid melting cycles – make high availability possible. To find out how these furnaces can boost your production, get in touch with Lectromelt – world's largest exclusive manufacturer of electric furnaces. Lectromelt Furnace Division, McGraw-Edison Company, 316 32nd Street, Pittsburgh 30, Pennsylvania.

WHEN YOU MELT... Lectromelt McGRAW EDISON

Circle No. 121, pages 157-158

128 PAGES OF FACTS TO ANSWER YOUR QUESTIONS ON CASTING ALUMINUM



Casting Aluminum is a highly informative manual published by the Reynolds Metals Company. It's available—free—to everyone concerned with casting. Hard cloth-cover bound, and profusely illustrated with photographs and diagrams, *Casting Aluminum* is a valuable asset to every technical library.

Get fast delivery on aluminum pig and ingot . . . contact your local Reynolds sales office for the name of the Reynolds Pig and Ingot Distributor in your area.

The amazing growth of aluminum makes understanding aluminum and its potentials doubly important—and this new book can help you realize just how you can do a better job with aluminum.

For your copy of the new Reynolds manual, *Casting Aluminum*, write to *Reynolds Metals Company, Box 2346FL, Richmond 18, Virginia.*

PARTIAL LIST OF CONTENTS

Pig and Ingot Classifications
Effects of Alloying Elements
Alloy Classifications
Aluminum Alloy Economies
Aluminum Casting Processes
Machining and Finishing
Alloy Selection
Aluminum Casting Design
Molding and Coring
Melting, Fluxing and Pouring
Trimming and Cleaning
Heat Treatment
Defects, Quality Control and Salvage

REYNOLDS ALUMINUM

Watch Reynolds new TV Show "Harrigan & Son", Fridays; also "All Star Golf", Saturdays—ABC-TV.

Circle No. 154, pages 157-158

Dampened Diaper Demonstrates Din Damping

by HERBERT J. WEBER

Dampening of a baby's diaper is analogous to damping noise with acoustical material. While my expert knowledge of the first part of the analogy does not qualify me to deal with the second, I shall proceed with the comparison anyway. Maybe the mothers will learn more from din damping than we will from diaper dampening.

A diaper will absorb a certain amount of moisture but after saturation, moisture passes right through. Just as the diaper has its limitations so also have acoustical-absorptive materials.

Sound-absorptive materials will soak up sound but like the saturated diaper will also let sound pass through. Thus if you want to enclose a tumbling barrel to keep noise from getting into the cleaning room, the one material not to use for an enclosure is acoustical tile, because the noise will leak through.

Sound behaves much like light. Hard shiny walls reflect both, and a thin curtain will transmit both. When sound strikes a hard shiny wall, it is reflected. Reflection in a room increases the noise level, prolongs noise through reverberation, and causes noise to spread through the room with little attenuation. When the walls of the room are covered with acoustical materials, these three effects of reflection are greatly reduced.

Now going back to the tumbling barrel. If you want to enclose it, so its noise will not get into the cleaning room, the enclosure should be made of hard, dense materials which will stop transmission of noise. Concrete is good but there are many other materials. If you enclose a swing-frame grinder and its operator in a booth made of hard dense materials, other workers outside the booth will be shielded from the noise. But the exposure to noise of the grinder operator in the booth will be increased. His exposure can be mitigated by use of acoustical materials on the inside of the hard walls.

Even a hard, smooth surface will absorb some noise because no physical surface is a perfect reflector of sound, light, or heat. Even a highly polished mirror will not reflect 100 per cent of the light incident upon it. In the table below, the noise absorption ability of various materials is compared to glazed concrete.

Material	Absorption ability* Ratio to glazed Concrete
Painted brick wall	1:1
Unpainted brick wall	2:1
Glass	3:1
Rough finish plaster on lath	4:1
Wood floor	5:1
Medium weight fabrics	7:1
Wood Paneling	8:1
Lined carpet	10:1
Heavy felt	14:1

**For noise frequency of 125 cycles per second. Absorption varies with various frequencies.*

Notice that paint lessens the sound-absorption power of a wall. This is because paint fills the pores of the wall thus stopping sound travel within the pores. Commercial acoustical materials are so perforated as to keep the effect of paint on sound absorption to a minimum.

Concrete prevents transmission of sound; absorbs little of it and reflects most of it. Whereas felt, as shown in the table, will absorb 14 times more noise than concrete or a painted brick wall. Notice that glass is a poor absorber of noise and is therefore a good reflector. Hence when foundry windows are open, as in the warm weather, there is usually a perceptible decrease in the intensity of the background noise.

You may have observed also that the newer foundries are noisier than the old ones. This is partly because the new plants have concrete floors whereas the old ones have sand floors. Sand is more absorptive and less reflective than concrete.

And so the baby's dampened diaper teaches us how to damp the din.

This Hopper on your truck

CAN CUT HANDLING COSTS 50%

Here's the fastest, lowest cost method of handling bulk materials and small parts—hot or cold, wet or dry.

One man with a Roura Hopper can do the work of two and do it in half the time. Loaded Hopper is picked up by the truck operator in a matter of seconds. Platform or forks slip into underframe and it can't slip off.

DUMPS ITSELF

Loaded Hopper is transported to its destination—operator trips the latch—and the Hopper automatically dumps its load, rights itself, locks itself.

RIGHTS ITSELF

Thousands of Roura Hoppers are now in use handling scrap metal, hot forgings and castings, cinders and aggregate, pickles—and dozens of other items.

LOCKS ITSELF

They're made in eight sizes, ⅓ to 4 yards capacity. Built of 3/16" steel plate with continuous arc-welded seams. Heavier plate if desired, also stainless steel or galvanized. Mounted on live skids or with a choice of wheels. Can ship standard models immediately.

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Circle No. 155, pages 157-158

How the Foundry Industry Serves America . . . #11 of a Series

IRON CASTING REPLACES WELDMENT IN SWIVEL FASTENER, CUTS COST 80%

Originally this swivel fastener was made as a weldment of two pieces of steel. Twelve separate operations in shearing, trimming, piercing, breaking, drilling, assembling and welding were required. The fabrication cost of $1.88, added to a material cost of 66¢, resulted in a total piece cost of $2.54.

By utilizing gray iron's ability to be cast in intricate shapes as a single unit even around a ball bushing, the manufacturer was able to eliminate the costly assembly and welding operations. And the part possessed better wearing and damping properties. After the conversion to gray iron, the simplified unit was fabricated and delivered by the foundry at a ready-to-go cost of only 52¢ each.

This is just another example of how modern iron castings can solve many of the problems of industrial design and effect substantial manufacturing savings.

For the production of structurally sound iron castings, Hanna Furnace provides foundries with all regular grades of pig iron . . . foundry, malleable, Bessemer, intermediate low phosphorus, as well as HANNA-TITE® and Hanna Silvery.

Facts from files of Gray Iron Founders' Society, Inc.

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Hanna Furnace is a division of **NATIONAL STEEL CORPORATION**

In the interest of the American foundry industry, this ad (see opposite page) will also appear in

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Circle No. 156, pages 157-158

DIETRICH'S CORNER

Lost-Wax Casting

by H. F. DIETRICH

To the shakeout man handling a seemingly endless stream of hot castings it matters little that he is following one of the oldest means of man's artistic expression. The fact is that this high production, precision casting, carload lot business in which we are engaged began a few thousand years ago when a sculptor, a bricklayer and a couple of bees got together to make some of the most amazing castings the world has ever seen. Like creatures living on an isolated island of civilization, the followers of this ancient art have kept the lost-wax process alive.

The rest of the world advanced through various stages of civilization; from the artistic mace through the brass cannon, to the Big Bertha of WW-I, to the Sherman tanks of WW-II. But these statuary casters plodded along in the traditional way making artistic bric-a-brac to be appreciated by man in his leisure moments only.

I recently met a number of these artists at what was billed as a Bronze Casting Conference. Now I thoroughly enjoy conventions, conferences and seminars. My reasons for enjoying conventions can be understood by any foundryman who has been to one of our National gatherings. My reasons for enjoying conferences and seminars are less obvious and escape me for the moment. But while attending them, you do meet a lot of nice people.

After I registered and looked around to see if any of my friends were present, I knew I wasn't among foundrymen. Have you ever seen a foundryman gazing at a polished, misshapen block of marble enraptured by its design, or studying a painting to determine the author of the brush strokes? I don't mean to imply that all foundrymen are uncultured boors, but in me the quality of culture must be dormant, or nonexistant, because to me some phases of modern art appear to be the doodling of a neurotic orangoutang. These good Followers of Michelangelo flipped over it.

At dinner I was joined by a young lady and two gentlemen who started a discourse on the euphonic effect of reflection angle relative to the harmonic waves of pure sound. When the discussion advanced to the trigonomerical triangulation of wave incident, they lost me. With my vocabulary limited to high class profanity, and my knowledge of physics concentrated on the relative merits of Scotch and Bourbon, I was clearly involved in the wrong discussion group.

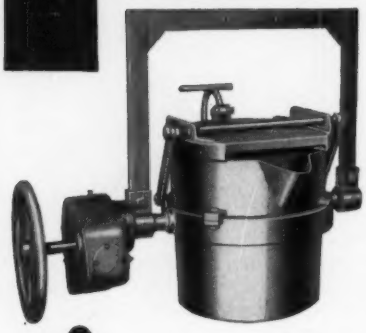
The next day during workshop meetings, I learned to know these distant cousins of ours. They were really a nice group to talk to, and they were there for just one purpose, to learn about bronze casting.

To a foundryman trained in the car-load-lot field, it is amazing to see such a to-do made over a single casting. When we see a pattern most of us think in terms of potential quantity production. Everything must be made foolproof and in a hurry. We dream of jigs, fixtures, conveyors, and methods by which we can turn them out by the thousands. We are taught to think BIG. In the process we lose sight of the fact that the casting has a *Shape*.

To the wielder of the plaster bucket, the latex and the chasing tool, time is a negative factor. They are proud of their work and they are interested in only one thing—to get *one* good casting. In this group of artists only remotely connected with our industry, I found true appreciation of the beauty of castings.

It is hard to believe that this mechanized, gadget studded, cost-conscious business of ours began as an artistic expression of man. To those who think this single casting business is a waste of time, I have only one answer. I have never seen an automotive casting placed on a pedestal in a park for public display.

easy
one-man pouring on smaller jobs



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TYPE 10 BCR incorporates all the "big ladle" features for precision control—yet it's specially designed for easy, one-man handling of the entire pouring operation. Offers these features to assure safe, fast and accurate performance: Easily removable sealed Anti-Friction Trunnion Bearings; Taper Side Welded Bowl with Lugs attached; Bowl Cover; and Universal Square Bail drilled for Distributor.

Send your pouring problems to us. Ask for the latest catalog on our complete line of standard and custom pouring and handling equipment.

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Circle No. 157, pages 157-158

Use Post-course Information for Better Castings, Bigger Profits

by RALPH BETTERLY

In the September issue of MODERN CASTINGS (see page 25) ten points were proposed as important considerations if the metal casting industry is to realize maximum return on its investment in out-of-plant training courses. To further elaborate the importance of some of these points, this column in the October and November issues covered No. 5 *Select the Right Men* and No. 3 *Select the Right Course*, respectively. Let us now consider the "touchdown" aspect of all training courses—No. 7 *Post-Course Application of Information.*

Intelligent use of the returning "student" and his knowledge is, in many ways, the most crucial consideration in the realization of good returns from your training investment.

In the July column, this writer discussed the differences between "telling" and "teaching". It was pointed out that teaching should motivate the recipient to take action; to try better ways to accomplish things—in short, to apply the new knowledge.

An out-of-plant trainee who returns home full of enthusiasm and drive, only to find resistance to his new ideas, quickly becomes bitter and cynical. Such frustrations will seriously reduce his creativity and productivity. Unless he is given opportunities to demonstrate and apply new information and newly-developed skills, he can easily become a less-valuable employee than he was before receiving special instruction.

It must be kept in mind that such an employee, if not carefully selected and placed, can return to an environment where departmental or organizational personnel relations can be strained. Far too often, promising and intelligent trainees are returned to work under superiors who resent this special training. Such supervisors are not receptive to new ideas proposed by returning "students". The value of intensive technical training should not be jeopardized by placing the trainee where supervisors consider his suggestions to be a lot of new-fangled academic nonsense. New knowledge and techniques should at least be *tried.*

Conversely speaking, neither should the returning student be given a free hand. Some trainees under these conditions may figuratively "raise the roof" or "jump on their horse and ride off in all directions." Compromises must exist. Management and supervision should sit down and carefully consider the application of new ideas to their own operations. But, above all, the "student" involved *should be challenged.* Lack of interest in him through poor organizational climate or the failure to assign greater responsibility can nullify any training values received.

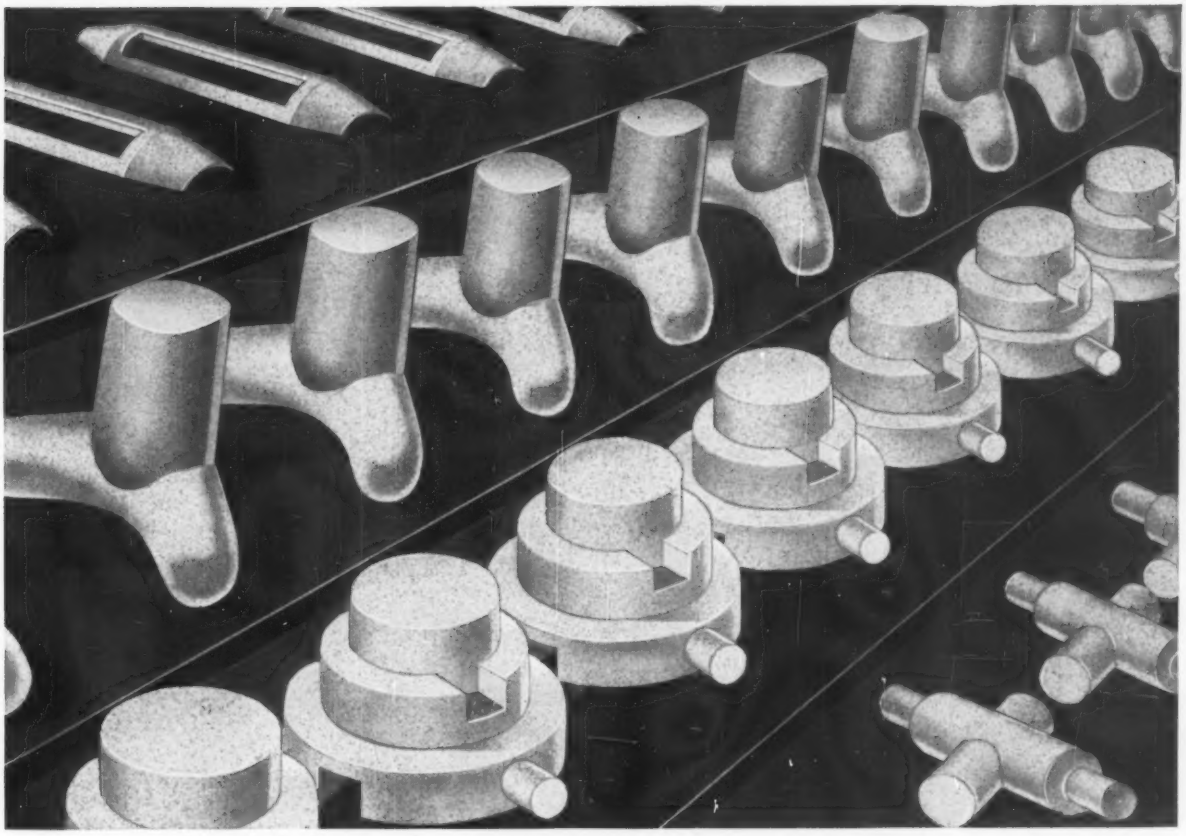
Some managements utilize outside training as special steps related to previously-planned personnel upgrading.

To receive maximum benefit from outside training, the returning man's skills and knowledge should be used immediately. He should be given an *opportunity* to report to his superiors on new ideas. If he knows this prior to the course, he will probably put forth greater effort when the instruction is presented.

When specialized intensive instruction has been given, the recipient should also have an opportunity to relay pertinent knowledge to his associates or department. Metal casters, having a specific problem in a course area, can benefit from the returning student if his energies and knowledge are intelligently applied. He can be assigned to a specific troublesome problem or better yet, his abilities can be used to *instruct* other employees. He can also be an asset in modernizing the plant's own training courses.

ing management should recognize

In using outside training, metalcast- that *investment return* is possible only through definite post-course plans and prompt *application.* This is the "pay off"; the "touchdowns"—better castings and bigger profits.



How New QO FURSET Resin Binders CUT CORE AND CASTING COSTS

Look at how QO FURSET can cut the cost of your foundry cores while simplifying final operations on your castings:

1. **Speed.** Cores in 15-30 seconds provide low production cost. Depending upon the size of the core and the heat of the box, cores are ready for removal from a hot core box in 15-30 seconds.
2. **High Strength.** Dry tensile strengths of 350 psi are obtained with only 1½% QO FURSET on clean sand.
3. **Easy Shakeout.** QO FURSET is designed for easy shakeout in both ferrous and non-ferrous castings to assure low cleaning costs.
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QO FURSET Offers Both Ferrous and Non-Ferrous Grades

QO FURSET Binder A-4090 is designed for use in ferrous foundries where hot strength and minimum gas evolution are desired.

QO FURSET Binder A-2590 provides somewhat lower hot strength and is designed primarily for use in non-ferrous foundries where low temperature collapse is desired.

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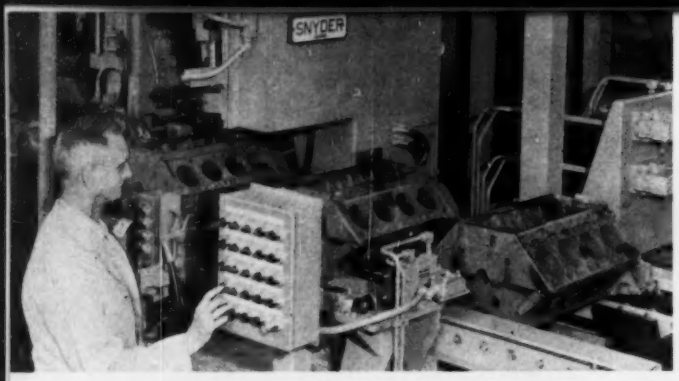
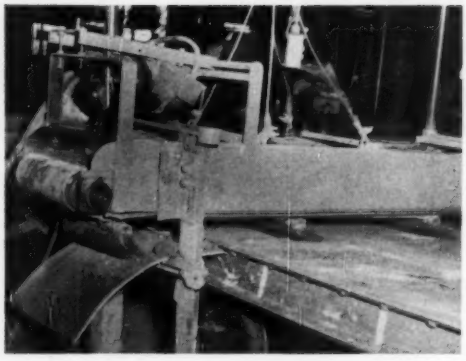
Circle No. 158, pages 157-158



Here's How . . .

the latest foundry developments may help you perform a better job.

. . . cast iron V-8 engine blocks are automatically de-finned at the rate of 240 per hour. This special transfer type machine was designed and built by Snyder Corp., Detroit, uses air cylinder-actuated steel punches and chipping tools driven by air hammers to remove fins from the entire casting. Fins are first removed from ends then rotated and fed into next station where top and sides are de-finned. Castings are again rotated and remaining surfaces cleaned in third section of machine. Castings slide on rails and are accurately located at each de-finning station by locators that engage bearing or plug holes. Another machine in the system rough grinds all casting faces. This mechanized breakthrough has eliminated the laborious and consuming hand grinding and chipping that has so long characterized motor block cleaning.



. . . sand and metal spatters are cleaned off merry-go-round mold conveyor at Sealed Power Corp., Muskegon, Mich. by a plant-made unit operating at right-angle to the conveyor. Regular pushbroom brushes are attached to a power-driven rubber belt conveyor. They continuously brush across the mold conveyor as it passes under the sweeper.

. . . to construct and operate safe X-ray inspection facilities Bonney-Floyd Co., Columbus, Ohio, crane operator stands near the control cabinet facing a swinging aluminum door which closes off the radiography room. Door must be locked from outside, key removed and then inserted into control cabinet lock before x-raying of casting can start.

. . . chemical analysis time is reduced from eight hours to 15 and 20 minutes at Rosedale Foundry Co., Hicksville, Long Island, N. Y. General Electric x-ray spectrometer is used to analyze for all elements from and including magnesium in the periodic table.

With Mogul you can see the difference!

For years, experienced foundrymen have looked to Mogul Cereal Binder to help them consistently turn out top-quality cores. First choice in cereal binders, Mogul gives perfect green bond, offers unusual dependability in spite of usual wide variations in mulling time, types of sand, core shapes and sizes. Mogul provides high green strength; cores hold their shape during handling and storage. They give good collapsibility and easy shake-out, cutting down on strains and hot tears. The excellent permeability of Mogul reduces costly blows due to inadequate venting.

Today, teamed up with Dexocor the *dry* replacement for core oil, Mogul performs better than ever. For outstanding performance on green bond, green sand, for better blowing, easy ramming, easy shake-out. all-around improved handling and more efficient production, the combination of Mogul and Dexocor is unbeatable.

Your Corn Products technical representative is completely versed in the application of these and other binders and dextrines to mold and core making. Backed by years of experience, a completely equipped foundry laboratory, and the extensive facilities of the world's largest corn processor, our technical representatives will be pleased to work with you to help develop the combination of binders that's right for your needs. Call our nearest sales office or write direct.

MOGUL® cereal binder

CORN PRODUCTS COMPANY INDUSTRIAL DIVISION • 10 East 56 Street, New York 22, N. Y.

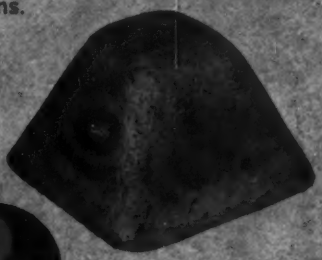
Other fine products for the Foundry Industry: DEXOCOR® • KORDEK® binders • GLOBE® dextrines

Circle No. 122, pages 157-158

Tramp elements begone!

GLOBE SILVERY IRON is virgin metal produced in a blast furnace from natural iron ores. Tramp elements are therefore at a minimum.

Closer chemical and physical control in the cupola is possible when Globe Silvery is used and you avoid the need for highly concentrated alloy additions.



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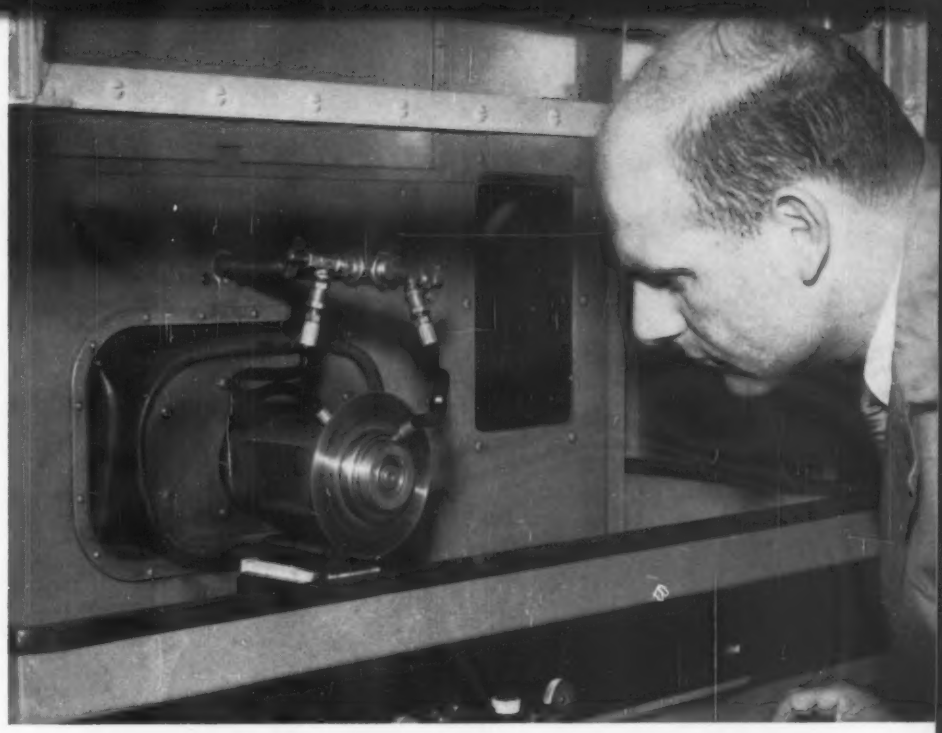


Rapid Obsolescence of Machine Tools Sparks Need for Quality Castings

American industry is now burdened with an estimated $95 billion of obsolete machine tools and related equipment. The compelling pressures of competition make modernization a must for survival.

THE BIG EMPHASIS today in machine tool capability is greater productivity with better quality at lower unit cost. Machines built as recently as three years ago have been rendered obsolete by new designs which will do a job in a half, a third, or even a fiftieth of the time formerly required. Tolerances are now being measured in "millionths" of an inch instead of in "thousandths."

Metalcastings provide the reliable skeletons and muscles of these modern tools. Close to $60 million worth of castings are used in building a year's output of machine tools valued well over a billion dollars.

The vigor of this big market opportunity for metalcastings is vividly portrayed in the swing to automation. Practically every modern machine tool can now be equipped with electronic numerical control. This new industrial concept replaces human control with magnetic tapes, punched cards, or punched tapes. A complete sequence of machinery operation can be repeated indefinitely so each part is identical to the previous. Time savings are often as high as 90 per cent. And the opportunity for human error is nil. The hydraulic actuating mechanisms needed to follow the tape "commands" are opening additional markets for pressure-tight castings.

The swing to high speed mechanized automated machining is having a big influence on customer demands for better castings. For automation to work, every part, cast or otherwise, fed into the machining set-up must be consistent in quality and dimension. The machine makes no human errors but it can't adjust for variations in the casting on which it is working. This explains why many casting customers have seemed almost adamant in their insistence for better quality castings. One manufacturer has an automatic machine line where 160 individual tools are used to machine each casting!

A Special Report

by Jack H. Schaum

Assisted by

R. W. Erickson, Chief Engineer, Mach. Tool Div., Barber-Colman Co., Rockford, Ill.

Paul E. Garlock, Asst. to President, Leland-Gifford Co., Worcester, Mass.

Charles Hall, The Heald Machine Co., Worcester, Mass.

Robert T. Hook, Chief Metallurgist, Warner & Swasey Co., Cleveland, Ohio

Morris L. Hutchens, Vice President, Engineering, Kearney & Trecker Corp., Milwaukee, Wis.

C. W. Marshall, Process Eng., The New Britain Machine Co., New Britain, Conn.

Ronald Scofield, Manager of Engineering, Turning Dept., Jones & Lamson Machine Div., Springfield, Vermont

Lloyd Sheflo, Adm. Engineer, Giddings & Lewis Machine Tool Co., Fond du Lac, Wis.

Donald R. Skudstad, Engineer, Gisholt Machine Co., Madison, Wis.

G. D. Stewart, Chief Engineer, Machine Div., Ex-Cell O Corp., Detroit, Mich.

Recent demands for standardization of machine tool components by car and other mass producers has led to industry adoption of a "building block" concept. Interchangeability of units permits rapid and inexpensive re-tooling for model changes or production line innovations. As a result one tool builder can create 132 different machine combinations to handle various manufacturing operations.

Machine tool business has been slow now for some time. Second quarter of 1960 slipped 15.5 per cent below first quarter. This was 10.5 per cent below the previous year. Export business has been one big source of strength. In June, foreign orders accounted for 41 per cent of total U. S. cutting tool business. Foundries with their production tied to machine tools have been hurting for close to a year. For here is an industry that in good years needs well over 160,000 tons of gray, ductile, and malleable iron castings, 6000 tons of steel castings, 3,800,000 pounds of copper base castings, and 1,900,000 pounds of cast aluminum.

Current Business Problems

Some machine tool executives feel that unrealistic government tax write-offs are big stumbling blocks to their prosperity. On this subject, H. H. Whitmore, executive vice president, Jones & Lamson Machine Co., says: "We must achieve accelerated productivity—more goods per man hour. To do this, we must be free to modernize our plants, devote more money to research and development, and replace machines which, being outmoded, create bottlenecks in our production lines.

"Unrealistic depreciation rates contribute to the continued use of old, uneconomical machine tools in the United States, and as the Senate Small Business Committee reported last January, these outmoded depreciation policies have probably stifled our economic growth."

For instance a three year old machine tool can be rendered obsolete by today's fast moving technology. Yet the owner still has 17 years left in his depreciation schedule to write off its cost. Faster tax write-offs seem to be the logical answer.

Where does metalcasting fit into the machine tool building industry? What castings are they using? How can we get a bigger share of their fabricating business? These are the questions.

And here are the answers obtained by Modern Castings from many of the leaders in this industry so vital to foundry prosperity.

Consider first the complexity of the machine tool market and how basic it is to our gross national product. Almost every item manufactured today owes part of its existence to such machines.

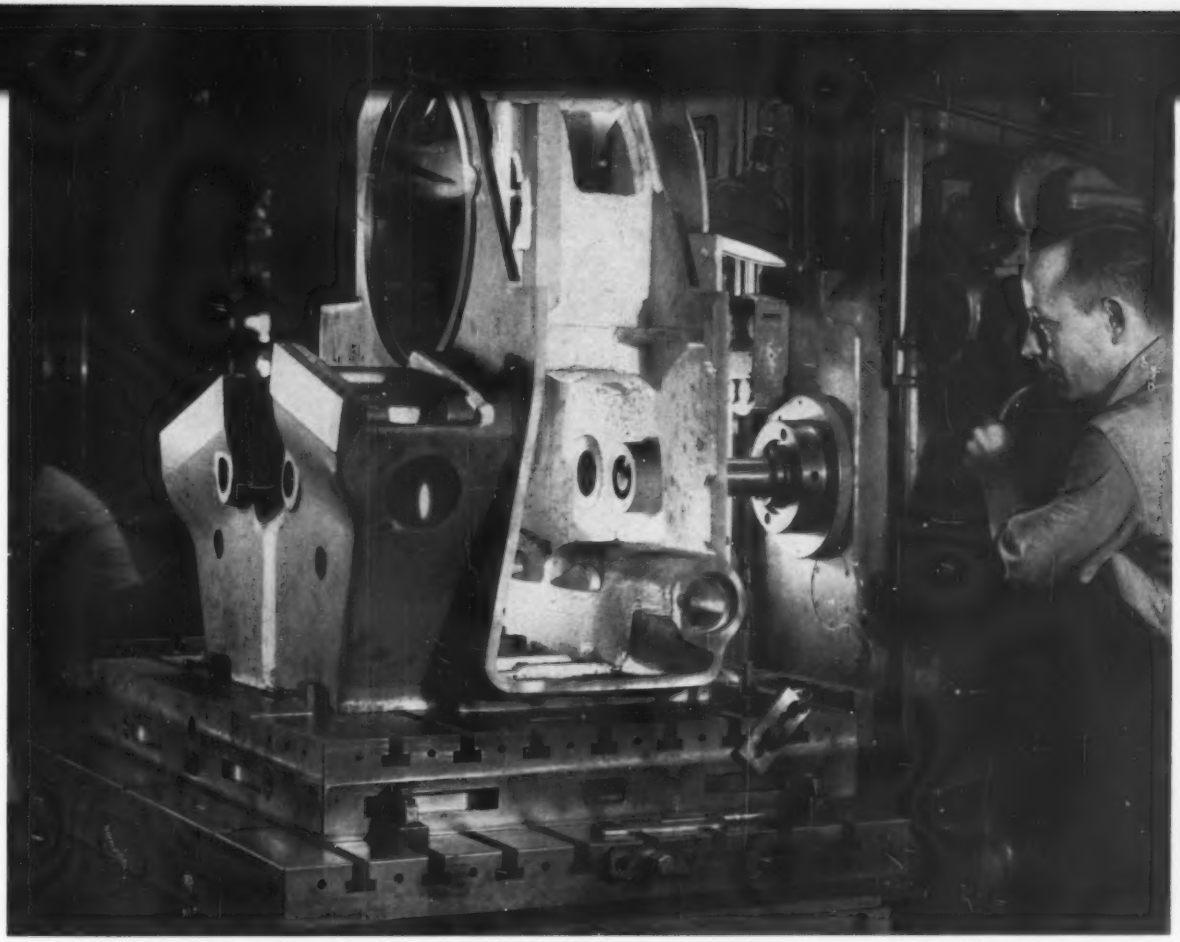
Basic Machine Tools

The term "Machine Tools" embraces a tremendous variety of devices used to shape material into final configurations needed to perform vital functions.

There are over 1000 specialized variations of the basic types of machine tools. Also many are combined into one unit to perform multiple duties. The ultimate goal of the machine tool manufacturer is to build equipment with infinite rigidity and zero cycle time capable of producing parts with an accuracy of "± nothing".

Gray iron accounts for the greatest tonnage of the castings going into tool building. According to the manufacturers, it is the extreme rigidity and long-time stability of gray cast iron that has led to its popularity for lathe beds and head stocks. The ability to surface-harden the bed ways for maximum wear resistance while the rest of the casting maintains its excellent machinability also adds to the popularity of gray iron. The presence of graphite in the iron imparts the best vibration dampening capacity of any material capable for this rugged service. Combine these plus points with relatively low cost and you can appreciate why machine tool builders prefer gray iron castings for:

- Lathe beds
- Head stocks
- Saddles
- Aprons
- Cross-slide carriages
- Turrets
- Sleeve bearings
- Levers
- Hinges
- Hinge plates
- Tool holders
- Cam drums
- Index arms
- Guard rings
- Gear boxes
- Clutch sleeves
- Adapter couplings
- Coolant distributors
- Indexing skiders
- Motor housings
- Spindle indicator housings



Machining drum housing and cross slide piece for six-spindle automatic bar machine.

Brackets	Drill press columns & ways
Pedestals	Quill heads
Bases	Drilling machine table
Hydraulic pump bearings	Riser blocks
Rams	Legs.
Covers	

Gray iron is not the only cast metal going into machine tools. Steel castings are used for levers and cutting tool blocks. Covers, guards, and some housings are cast aluminum. Bronze bushings, lead screw nuts, shifters, worm gears and sleeves are also cast. A growing interest in the relatively new material, ductile iron, has led to its use for tables, levers, hinges, hinge plates, and tool holders because of its high modules. Besides the variety in metals, sizes range from big sand castings weighing over 20,000 pounds down to investment castings lighter than one pound.

When questioned by MODERN CASTINGS on: "Why do you use castings to build machine tools?" machine tool builders said:

1. Easy to cast complex designs.

2. Prices of castings are usually below other fabricating techniques —the higher the volume and complexity of parts the better showing castings make.

3. Pressure tight castings are well suited for hydraulic pump parts.

4. Rigidity through mass easily achieved by casting.

5. Ability to cast closer to size in recent years is saving machining time and expense.

6. Gray iron castings are especially stable, can be surface hardened, machine easily, possess extreme rigidity, and have superior damping capacity.

C. W. Marshall, Process Engineer, The New Britain Machine Co., states: "We prefer castings because of their eye appeal, freedom of design, ability to function, stability, and low cost in most cases."

Metalcastings don't have a monopoly on success. Machine tool builders make use of other fabricating techniques—especially welding. If only a very small number

Basic Types of Machine Tools

Drilling machines	Duplicators
Tapping machines	Planers
Boring machines	Shaving machines
Turning machines	Trimmers
Presses	Grinders
Lathes	Milling machines
Sawing machines	Screw machines
Drill presses	Facing machines
Chucking machines	Press brakes
Shapers	Draw presses
Profiling machines	Drill pointers
Threading machines	Contouring machines
Broaching machines	Lapping machines
Optical comparators	Automatic bar machines
Electro-spark machines	Die sinking machines
Forming machines	Routers
Hobbing machines	Punches
Honing machines	Riveters
Shears	

of machines are being built it is often too expensive to build pattern equipment. For the customized unit it is sometimes cheaper to create the machine by welding fabricated steel sections.

Welding advances outpaced metal casting technology until quite recently. Many foundrymen are just now beginning to regain a lot of ground lost to this competitive process. A number of others are pricing themselves right out of the market, forcing buyers to seek cheaper fabrications.

Foundrymen are still a long way from satisfying the ever-growing demands of machine tool builders. In their opinion many of the independent jobbing foundries have fallen so-far behind in modern practices and decent working environment that they are a disgrace to the metalcasting industry. Young engineers shun making their career in an industry that creates an unfavorable impression, in comparison with most other fields. If new blood cannot be attracted into the foundries they are going to fall even further behind.

Actually the situation has regressed to the point that many machine tool builders now own and operate their own foundries in order to get the casting quality and economy needed to meet their rigid requirements. Traditionally the captive foundries have had more dollars available to invest in capital improvements needed to meet demands of parent company. Closer liaison is usually possible between designers, engineers, foundrymen, machinists, and salesmen when under same management.

As a consequence metalcastings have only been able to maintain their status and grow in use where machine tool builders have developed reliable foundry operations. There is tremendous opportunity here for jobbing foundries to save-face and re-establish lost markets if they will make a determined effort to raise their standards of casting quality.

According to opinions expressed by the contributors to this MODERN CASTINGS study, foundries could sell more castings if they would:

1. Build patterns for less money, but more ruggedly to minimize maintenance.

2. Ship castings completely snagged, cleaned, repaired, and painted.

3. Install heat treating equipment so castings can be delivered with proper physical properties.

4. Introduce quality control programs that will guarantee consistent reliable properties that meet exacting specifications.

Machine tool builders would be helped by: a low cost, low production, precision casting process; cast high alloy steel gears; aluminum dial rings with cast-in graduations; cast leveling screws and hold-down screws in bases; and cast flanges around openings that would require no machining.

Foundrymen are fortunate in that most of the machine tool builders have a thorough understanding of the advantages of metalcastings and a strong desire to use them wherever possible. But they are realistic in their insistence that the cast parts meet competition in both quality and price. Foundrymen's share of this market will depend on their ability to apply technology for profit.

Warner & Swasey Uses Castings by the Tons in Machine Tools

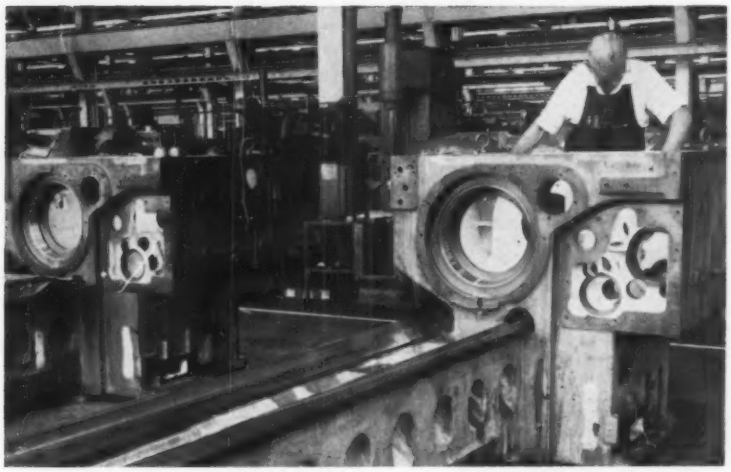
Gray and ductile iron provide strength and rigidity needed in today's high-speed, highly mechanized metalworking operations.

SOME 13,800,000 pounds of gray and ductile iron castings were used by The Warner & Swasey Co. last year in producing a variety of turret lathes and automatic chucking machines. Metalcastings provide strength and rigidity to machine tools, two qualities needed to meet the rugged service and dimensional stability demanded of this equipment by industry. A machine tool can be no more accurate and reliable than the metal in its individual components.

As proof of their belief in the suitability of castings for constructing precision tools Warner & Swasey uses gray iron for lathe beds and headstocks, saddles, aprons, cross-slide carriages, turrets, sleeve bearings, levers, hinges, hinge plates, tool holders, brackets, cam drums, index arms, guard rings, worm gear boxes, clutch sleeves, adapter couplings, coolant distributors, and indexing spiders. In addition, cast aluminum bronze worm gears are also used.

Relatively new to the industry is ductile iron. But Warner & Swasey is already using about 125,000 pounds of it a year for levers, hinges, hinge plates, tool holders, and brackets. These applications require higher strength and ductility than afforded by gray iron.

One of the largest castings now being used is their 9000 pound, integral cast, lathe bed and headstock. The metal is ASTM-A 48, Class 50, gray iron analyzing 3.00% C, 2.15% Si, 0.25-0.40% Ni, 0.15-0.25% Cr, and the balance Fe, Mn, S, and P. The ten foot long bed ways are hardened in their special induction hardening machine. A conventional planer was modified to slowly move the lathe bed under two custom designed induction coils at a speed of 3.4 inches per minute. Coils are connected to a 50 KW 450,000 cycle generator. Induction current heats metal skin to 1550 F. An air and water



Universal turret lathe showing integral cast bed and headstock.

quench, built into the coil, complete the treatment.

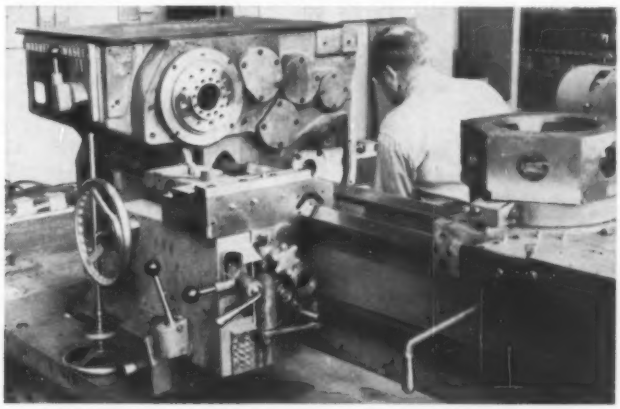
Result is a lathe-bed way with a 75 scleroscope hardness. Ways are then ground to a 25 RMS finish. Precision ground vee-type bedways are the foundation for long lasting machine accuracy. Gray iron castings are particularly suited to meet the requirements for lathe beds.

The complex configurations and large number of holes designed into a lathe bed shows the value of sand molds and cores to economically shape molten metal into finished product. Gray iron has the long-time stability, rigidity, and dampening capacity required for four decimal point accuracy needed in today's modern machine shops.

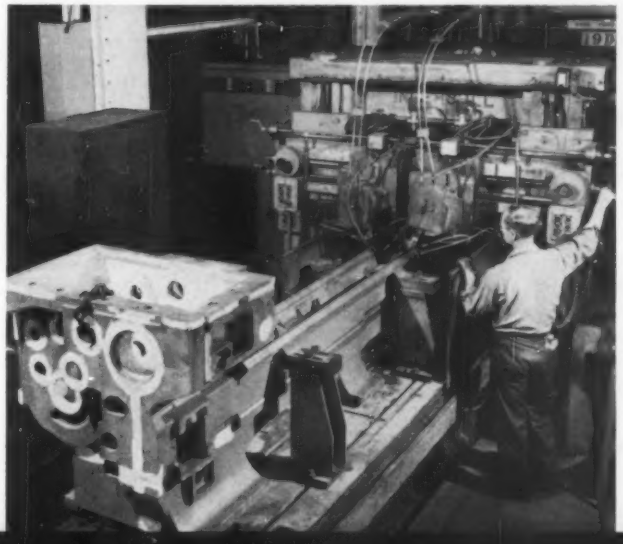
As assembly proceeds on a turret lathe, more and more castings move into the picture—cross slide, carriage apron, hex turret, and saddle apron—all quality gray iron castings.

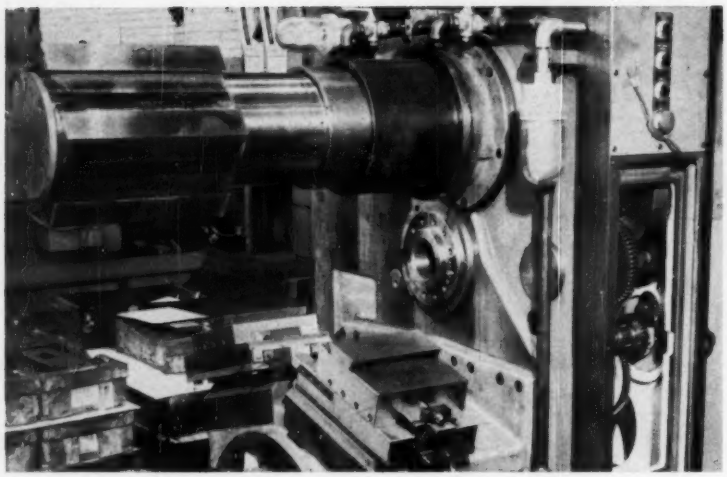
High speed mechanization has been a boon to new demands for machine tools. As a result, changing designs are creating new markets for castings. An example is the single spindle automatic chucking machine. Close tolerances, heavy metal removal, and increased production at lower costs have skyrocketed sales of this tool. A cast

Assembling components of headstock. Castings contribute greatly to the stability of large precision lathe.

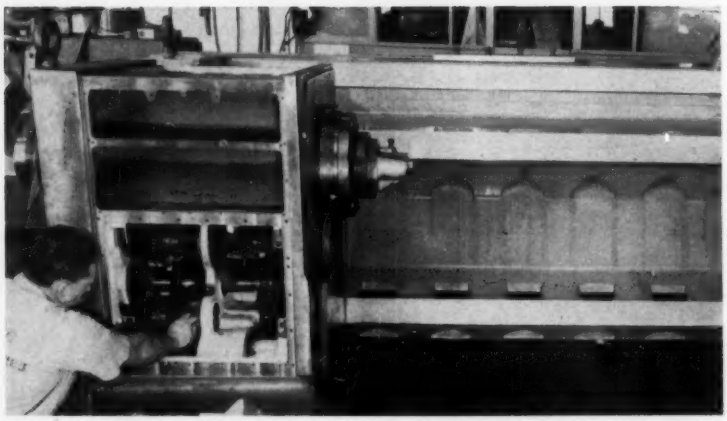


Special induction hardening machine with air and water quench heat treats the 10-foot gray iron lathe bedways.





Single-spindle automatic chucking machine uses special class gray iron sleeve bearings for sliding, rotating shafts.



Operator installing gear mechanism on servo turret lathe. Generous use of castings throughout is shown by this model.

gray iron head supports all the drive mechanism as well as the pentagon bar. Attached to the lower left side of head is the rugged cast iron support for the cross slides. Tools mounted on the slides face and form outside dimensions while 5 stations on the pentagon bar hold tools for turning, drilling, boring, reaming, tapping, and internal machining in automatic cycle sequence.

Just unveiled is Warner & Swasey's servofeed turret lathe with inclined bed. Equipped with a new concept in numerical control systems it can be operated by an electronic tape memory system which can record up to 96 consecutive commands. The inclined bed in the center and both end housings are gray iron castings, still holding their own in today's most modern tools.

Robert T. Hook, Chief Metallurgist, of Warner & Swasey Co., likes to use gray iron castings because "they can be adapted to almost any design, and analyses can be customized to suit the applications." Hook describes a rather unusual application for gray iron, a sleeve bearing for sliding rotating shafts used on automatic chucking machines. "We use a special class 20 gray iron made in an electric furnace. It has a very open structure loaded with coarse graphite. With this built-in lubrication we don't have to worry about galling between rotating steel shafts and iron sleeve bearings."

Warner & Swasey machine tools represent a rugged proving ground for materials and processes. And the gray iron castings parts continue to meet the test to which machine tools are constantly subjected in today's industry.

Here's casting technology from abroad that bears investigation by American metalcasters, who are determined to save time, produce more castings with the same labor force, and ultimately increase foundry profits. It shows how to . . .

Use Cement Bonded Sand to Increase Production

by H. Giese

Our gray iron foundry in Magdeburg, East Germany, uses the cement mold process to increase productivity without increasing workload. About 60 per cent of our total output, mostly medium and large size castings, are now made in cement bonded sand. Almost 80 per cent of our sweep work, formerly done in loam, is now made with cement bonded sand. About 90 per cent of all core jobs have been converted to cement. We make castings in job lots of many different shapes and sizes, the largest weighing 65 tons.

The mix consists of silica sand and Portland cement. The silica sand contains 85.3 per cent silica, 12.44 per cent feldspar, 2.26 per cent clay.

Screen Analysis: AFS		
	6-12	9.1%
	12-20	13.2
	30-40	22.7
	50-70	52.8
	100-140	2.2

This is a local sand which proves that special sands are not required for the cement process, as was generally believed. Clay content lowers permeability, but this sand is within limits that can be tolerated.

Best ratio of sand to cement is 8:1. Water is added at a ratio which permits further absorption of moisture from blacking and patch-up mixtures used when finishing the mold. By hand test, the prepared mix feels a little wetter than regular molding sand.

Of interest are recent experiments to shorten air setting time, such as: gassing with CO_2; use of sulfide compound additives; curing in dielectric ovens under either positive or negative pressure.

CO_2 gassing is particularly important because a core may be cured in 5 minutes. Although somewhat costly it may be justified in mass production of small and medium size cores where air drying up to 24 hours would require too much storage space.

The method is not economical for the very large size molds and cores. Assembly of such large molds requires many hours so that there is always ample time for the mold to air set.

Dry compression strength developes faster when CO_2 gassing is used than when left to air dry. However if a mold or core is allowed to air-set for 90 hours or more its dry strength will be higher than the one gassed with CO_2.

Cement bonded molds require special pattern construction. All new patterns are built-up of loose pieces grouped around a tapered wood core. When the pattern is drawn the wood core is pulled first. Then the loose pieces that form the interlocking wall segments of the pattern are drawn to the inside, away from the mold face.

A similar principle is applied in the construction of core boxes: "Better too many loose pieces than too few". Patching of torn edges and broken corners on a core is a tiresome job. If possible, cores should be made right side up to avoid rollover or excessive handling in general. Large size cores can often be built-up within the large mold cavity without the need for core rods or arbors. Considerable handling time is saved and possible damage to core surfaces is avoided.

The pit bed starts with a 4-inch layer of used dry silica sand. This is levelled and topped off with a layer of cement bonded sand about 1-1/2-inch thick, trowelled to a slick finish. After a short time for air setting the pattern is placed. Then 1-1/2-

inch layer of cement sand is built up around pattern to a height which can be reached conveniently by the molders. Backing sand—used, dry, unscreened sand—is filled in immediately. Air-setting of the cement facing sand is fast because the dry back-up sand absorbs moisture from the cement sand. Permeability is high so mold venting is never required.

As the mold walls are built up in successive stages progressive air-setting of the mold face permits drawing of the pattern within a few hours. The cement should have hardened somewhat but should still retain some elasticity. At this stage damaged or cracked mold surfaces can be patched readily by applying moistened cement facing sand and trowelling it smooth.

Mold setting is indicated by its change to a lighter color. Then a blacking wash is applied. Our blacking is made of graphite, (90-95 per cent carbon, 33 per cent finely ground coke, and a sulfide compound additive. It has a heavy consistency and is applied as a single coating. The slightly hygroscopic cement mold face draws off the moisture quickly. As wash dries, uneven layers are carefully trowelled smooth.

Cores are set after the entire mold has completely air dried. For a cope we are now using a heavy cover plate instead of a cope flask. The cast cover plate, provided with holes for sprues and risers, is faced with a layer of cement bonded sand 1-3/4 to 2-1/2 inches thick.

Gates and risers should have larger cross sections than normally used in conventional sand molding because the cold cement mold has a greater chilling effect. The result is a closely grained iron.

Example

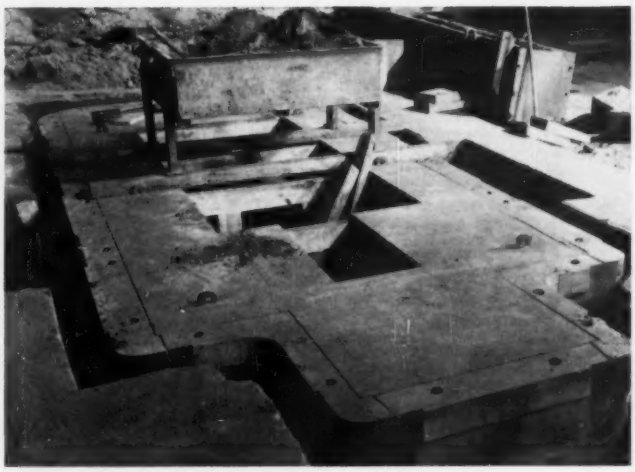
Cores are made of the same composition as the molds—an outer layer of cement bonded sand with dry silica sand as a filler. Core rods and arbors should be coated with cement facing mix to assure a uniform bond throughout the core. Applying the coating makes the core too strong and may lead to hot tears or poor core collapsibility.

The cement facing sand forms a 3/4 to 1-1/4 inch thick shell on the cores. Cores air-dry in 6 to 24 hours, depending on size. Subsequently, a single coating of blacking is applied.

Large gray iron housing: length 18 feet, width 8 feet, height 5 feet, weight (as cast) 20 tons, pouring time 60 seconds, pouring temperature 2270 F.

The housing is molded bottom up. Since this is a repetitive job we prepare a semi-permanent cement mold that can be used over again for about 10 of these large castings. Instead of making a complete new mold each time, we only place a new lining of about 1-3/4-inch cement sand between the outer mold face and the pattern. The enlarged, semi-permanent mold is made from the regular pattern superimposed by a skeleton frame.

The previously described molding method is followed. However, the facing for this mold is made from a 1:3 cement to sand mix which will have considerably more strength than the facing used for the regular mold. Used dry silica sand is used for back-up. Blacking is applied after mold is completely air dried. This protects the mold face during shake-out.



Local silica sand is used in cement-bonded process.

Before the pattern is placed, a new pit bed is prepared as previously described. Now we only have to build up a layer of cement bonded sand between permanent mold face and pattern. Only where the outer, permanent mold could not follow closely the contours of the pattern because of undercuts do we use dry fill to bridge the wider gaps.

To speed air drying time the pattern is drawn as soon as the cement sand has hardened sufficiently to hold its shape. Blacking is applied after the mold has air-dried completely.

Cores form an inner wall within the large mold cavity. The space in the center is filled with dry, used sand. This loose mass of dry sand rests on a plate laid previously over the pit bed. Lift hooks reach from the plate to the top surface of the core. They are positioned in such a way that they can be clamped to the poured off casting later on. Casting and core, plus loose fill, can then be lifted together from the pit. The dry fill inside the core comes to within 1-1/2-inches of its top edge. It is covered with a layer of cement bonded facing sand and finished to a slick trowel finish.

To make cores, cement sand is pressed against the inside walls of the core box. A layer 1-1/2 inches thick and 6 inches high is built up all around sides of box. Then the clam shell drops used, dry sand into the hollow center. The next layer is applied, filled with dry fill and so on, until the full height of

Cores form an inner wall within the large mold cavity, dry sand is in center

the box has been reached. Despite its great bulk this thin 1-1/2-inch layer of cement sand around the center of unbonded sand will make a perfectly satisfactory core.

We realized a saving of 20 to 50 per cent in man-hours applied to molding, core making, and cleaning time. Molder and core maker do not ram up or vent the mold or core. No reinforcing nails in mold or core face have to be used. Use of dry sand for fill simplifies and speeds up shake-out and cleaning operations.

Core ovens are eliminated. Savings in fuel are considerable. Cost of material handling is reduced because cement cores do not have to be transported back and forth to the ovens.

On repeat jobs the use of a semi-permanent cement mold increases productivity. Quality control is simplified. The cement mold has a higher compression strength and higher permeability than the dry sand mold. Scabs or swells are completely eliminated. Finally, highly skilled molders are not required for this method.

Pouring time for 20-ton housing is 60 seconds.

Cores dry in 6 to 24 hours depending on size.

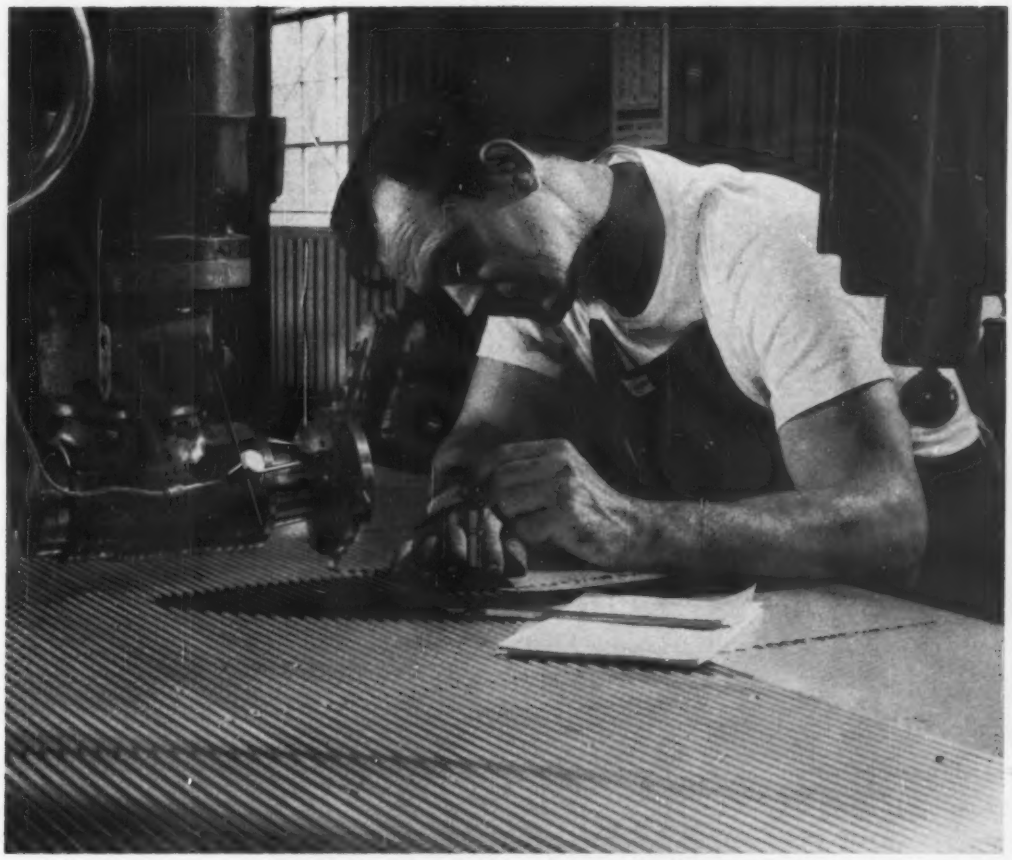
They've Cast An Aluminum Skyscraper

. . . well almost. They have just completed a 43-story building in Mid-town Manhattan that has a "skin" of cast aluminum spandrels. This casting "first" opens the door on a complete new use for top quality castings, designed for beauty, durability and easy assembly.

by WILLIAM A. MADER,
Vice President,
Technical Services,
Oberdorfer Foundries, Inc.

CAST ALUMINUM has found another new market opportunity in the jungle of city skyscrapers. Showplace for this promising application is the recently completed 43-story First National City Bank Building, 53rd and Park Ave., New York City. It is faced with 6000 cast aluminum spandrels, and is a dramatic combination of architectural imagination and foundry skills.

The big job of producing these decorative, yet functional, castings was awarded by Reynolds Metals Co. to Oberdorfer Foundries, Inc., Syracuse, N. Y., the largest independent non-ferrous foundry in the United States. Some 46 different sizes of cast spandrels, ranging from 4 feet x 4 feet to 4-1/2 feet x 9 feet, and from 75 to 200 pounds, were used in the structure. The spandrel section thickness was only 7/16 of an inch, a real challenge to foundry gating and pouring ingenuity. An attrac-



Design is milled into cast spandrel for lantern.

tive, blue-gray finish was imparted to the exterior fluted surface of all the spandrels by an anodizing treatment.

Scheduling this $900,000 order in our foundry represented a real challenge. Not only did the various sizes complicate our problems, but they had to be cast in sequence to permit delivery on site —a floor at a time—to meet the construction time-table. This schedule, in turn, had to be integrated with anodizing treatment at H. A. Leed Co., Hamden, Conn. The production picture was further complicated by imaginative pattern engineering which permitted seven basic patterns to be modified by cutting off or adding segments to meet size specifications. This up-stream thinking saved about $30,000 on pattern and tooling costs.

The entire castings order, totalling some 750,000 pounds, was completed and delivered in about seven months. Aluminum castings proved all-round superior to other metals and fabricating techniques because:

1. Flanges and bosses could be integrally cast to back of spandrels.
2. Fluted design easily reproduced on front surface while back surface was cast flat.
3. Spandrels had rigidity needed for building construction.
4. Anodized surface presented a permanent, attractive, weatherproof finish.

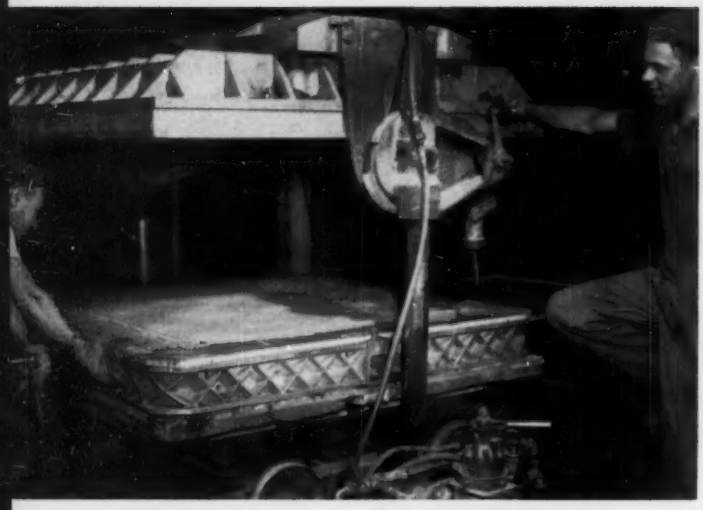
Production Techniques

Patterns for the job were machined from aluminum with fluted design formed in the drag half of mold. As many as 2624 castings of one popular size (4 feet 1-1/2 inches x 4 feet) had to be made. And as few as four of the largest spandrels were needed. Wood patterns were adequate for these. Except for the largest, all the spandrels were molded on jolt-rollover-draw equipment. Production rate was 75 complete molds per machine per 8-hour shift. The big ones were hand molded with pneumatic rammers. Hard rammed facing sand and flask bars every 6 inches provided the mold rigidity needed to keep the castings flat.

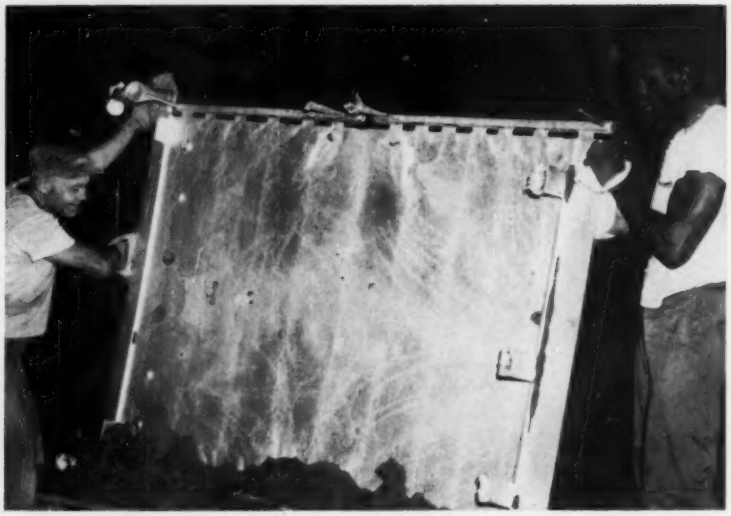
To run casting with such a large surface area and thin section, two ladles of metal were simultaneously poured into pouring cups on opposite side of mold. Each cup fed two separate sprues and runner systems. Risers were attached to the integrally-cast window mounting flange on one end of spandrel and weather seal flange on the other end. Fast, uniform pouring of alloy 43 (5% Si) at 1400 F provided clean, accurate castings. Alloy 43 was selected for its good fluidity and attractive anodizing characteristics.

Because of the large metal span, care had to be taken during shake-

Pneumatic tools are used to ram mold in aluminum cast spandrel production.



Molders complete drag section of machine mold.



Workers remove spandrel from mold.

out and subsequent handling to avoid sagging, bending or wrinkling.

Flanges on back of spandrel were milled and bosses drilled and tapped for attachment to mounting brackets.

Sand blasting and heat treatment proved to have a critical influence on final anodizing results. After homogenizing heat treatment, spandrels were carefully palletized and shipped to anodizing plant where they were immersed, ten at a time, in baths for 38 minutes. If any panels were off-color the anodized layer was stripped off, casting re-heat-treated and resand blasted. And the next time through, the anodizing was usually successful. All panels had to match and be flawless before installing on the facade of the building.

Acceptable spandrels were sprayed with a protective plastic coating and palletized for truck delivery to the National Bank Building as, and when, needed to meet construction schedule. This coating protected finish from plaster, paint, and other similar damage. Coating was stripped after installation was complete.

Spandrels were easily and speedly installed by slipping into position and tightly locking with mounting brackets. Thiokol rubber formed a seal between the spandrel and vertical mullion against which it was clamped. Window sill and frame overlapped to seal top and bottom of spandrel from weather infiltration.

To complete the construction job we also cast at Oberdorfer the copings, panels, and corners in matching anodized aluminum.

The savings in time and construction costs effected by this technique and material make it an extremely attractive combination for building skyscrapers. Cast aluminum panels also have a great future market potential as sun shields on buildings and for face-lifting old structures.

Rack of cast aluminum spandrels enters heat treat oven.

In today's competitive economy, jobbing metalcasters must meet a great variety of metal specifications.

Industry members are called upon to cast more than one composition during the day's cupola operations.

With this in mind MODERN CASTINGS *presents herewith a special review of techniques that show . . .*

How to Make Different Irons from a Single Cupola Heat

by F. E. KASCH
Foundry Engineer
Gray Iron Research Institute, Inc.
Columbus, Ohio

IT'S QUITE a challenge to produce one consistent grade or analysis of cast iron to close limits all during a day's run, and from day to day. Operators sometimes expect to obtain an accurate final analysis when they have only a crude conception of the chemistry of their cast iron scrap going into the cupola. The steel scrap generally available can vary widely in analysis. At times, even more uniformity is expected than actually holds true in a car of pig iron.

Add to this the important variables introduced by the fuel, the atmospheric or blast conditions, the nonmetallics, the human element, and the manner in which the cupola is constructed and operated, plus errors in sampling and chemical analysis. To produce known and controlled analyses of irons in a single heat, some of the factors or conditions that cause the variations in a single iron operation can be used to assist in changing from one iron to another.

There are several ways a foundry can produce different types of iron from a single cupola heat:

1. Change the metallic charge during the course of the heat.
2. Change the operating conditions, in addition to changing the charge.
3. Change the analysis in the ladle by either the addition of alloys and carbon or by removal of sulphur or other elements.
4. Change the analysis of a portion of the melted metal in another type of furnace.

Many foundries find it expedient to change only the ingredients in the metallic charge to alter the iron analysis and to pour off the "change-over" iron in noncritical castings. An extra split of coke or two is usually used between the different types of charges to effect a better separation. Due to operating characteristics in cupola melting, a sharp and completely controllable change is not possible. Considerably more change-over iron is produced than is commonly realized. Even that which is recognized adds up to a considerable amount.

In a 54-inch cupola melting 11 tons per hour, the recognized change-over will probably average 10 to 15 minutes. This involves approximately 2 tons or more of iron to be disposed of in noncritical castings. The amount will be greater in larger cupolas. In addition to this, the beginning and end of the change-over cannot be timed or detected exactly. Therefore a certain amount of somewhat off-analysis iron is also poured. So three classes of iron are involved, i.e. the original iron, the change-over iron, and the new iron type. Timing, weighing, and testing are the three most important controls available.

Timing requires knowledge of how much metal the full cupola

stack will hold under normal operation. With fixed charge weights, reasonably consistent piece size, and fixed coke splits, the total number of charges in the full cupola can be checked at the end of the day. The time of charging the last charge should be noted. Exclusive of any metal in the well or front-slagging spout at that particular time, the amount of metal tapped from then on, plus the amount of metal in the cupola drop, represents the amount in a full stack.

This can also be roughly checked by counting the charges needed to fill the cupola at the start of the heat. The initial coke bed has a known height. The final operating coke bed can be determined by examining the height of the melting zone as shown by refractory burn-out. The difference or the additional charges needed to fill an operating cupola can be figured.

Whenever the changed analysis iron is charged into the cupola, the time should be noted, as well as the stack height. If a charge-height indicator is not available, the charging man can give a good estimate of how many charges the stack may be low at the time. By having observered the melting rate of the cupola on previous days, and for the half-hour or so prior to the "new charge time," a good estimate of the time to expect the new iron at the spout can be made.

Weighing all taps of metal can be of considerable assistance in determining when to expect the new iron. The time of charging the new iron should still be closely checked, and an estimate made of how much original iron is in the stack. With a known melting rate, the expected arrival of the new iron can be checked both by weight and by time for optimum control.

Frequent checks or tests must also be made on the iron coming from the spout. Usually a properly made chill or wedge fracture test, fully interpreted by a competent person, can distinguish between most types of irons. Such a test is economical and relatively fast. Rapid carbon determinations, although a little slower, can be used to back up the chill test. Rapid analysis for other elements also can back up this test, though the necessary speed and equipment are not yet generally available. Melting point determinations that give fairly accurate carbon equivalents can be made at the cupola in a few minutes.

A chill test, however, is fast and inexpensive. Chill depth indicates carbon equivalent. If the gray portion is examined closely some estimate can also be made of the carbon content, and the silicon by difference. Residual alloys sometimes hamper interpretation.

Figure 1 illustrates the differences in the gray portion of the chill test or wedge fracture for various carbon levels. In general, the lower carbon irons have a lighter and finer gray fracture. The high carbon irons have a darker gray fracture, a more open grain appearance and a deeper area of the fine sooty black structure immediately behind the white iron.

As soon as the change-over iron is recognized at the spout, start pouring the castings reserved for this iron. Allowances should be made for the metal in the well, which should preferably be drained. The same is true of metal in a front-slagging spout and forehearth. Both complicate a quick and complete change-over, if not thoroughly drained.

Figure 2 and Table 1, shows the change-over at a foundry which used chill-test control, timing, and weighing.[1] Tables 2 and 3 record experiences at two other foundries.

Production and economic conditions sometimes necessitate an operation which changes only the metallic charge. The most thorough way to control and separate different grades of iron in the cu-

Fig. 1—Per cent of total carbon.

Fig. 2—Chill fractures on change-over from class 35 gray iron to white.

Table I.—Class 35 Iron Followed By White Iron

Type of Iron	Samp. No.	Time	Total Chill	Clear Chill	% T. C.	% Si	% Steel	Blast Vol. Cfm.	Blast Press. oz.	Melt Rate T/hr.	Total Tons
Class 35	1	2:21	13	10	3.36	2.08	45	8000	24	15	16
"	2	2:24	15	10		1.89					
"	3	2:27	17	15	3.26	1.93					
"	4	2:32	20	16		1.76					
"	5	2:35	26	20		1.72					
"	6	2:38	24	20	3.40	1.65					
Transition	7	2:45	30	24		1.65					
White	8	2:49			3.54	0.98	45	5000	14	10	11
"	9	2:54				0.45					

1. 48" dia. cupola, 2000 lb. charges, 64" initial bed, front slagging spout (1000 lb. cap.) 3000 lb. ladle
2. Coke splits, 260 lb. for gray iron, 200 lb. extra between gray and white iron, 190 lb. for white iron
3. Estimated change-over, 10 to 15 minutes—3000 to 4000 lb. of metal

pola is to melt one grade completely before charging the next. In between grades shut off the air and drain the cupola of all iron and most of the slag. The bed is then rebuilt to proper height, the new metal charged, and the air turned back on.

Extra coke can be put on top of the last charge of the original iron, and the air blast proportionally reduced as the stack empties. This minimizes excessive refractory burn-out while melting the last metal of the original iron mixture. This method of separating types of iron is practically a necessity when switching from gray cast iron to high alloy white iron or the even higher alloy austenitic gray irons.

Loss of expensive alloys by cutting off the alloy iron taps too soon, or starting them too late, in order to insure the necessary full alloy in the special iron can add up to a considerable amount of money. Also, the dilution of the gray iron with large amounts of alloy from the austenitic charges (and vice versa) can result in some martensitic gray iron that would be very harmful and not easy to detect in some castings.

Since this method sharply separates different irons almost completely, it is highly recommended for changing from soft iron grades to stronger grades. Counting the slightly reduced melting rate with temporarily reduced air, plus draining the well, and measuring and rebuilding the bed and recharging two-thirds or more full, the lost melting time for the cupola can usually be held to 30 minutes. Molding, melting, or pouring schedules should be altered accordingly.

For a clear picture of what is happening in a cupola during melting read the Gray Iron Research Institute report by Krause, Lownie, and Greenidge (1952 AFS (TRANSCTIONS).[2] This involved water quenching a fully operating cupola. All materials in the cupola in the arrested operating state were removed from the top down, layer by layer, identified according to exact position, and examined visually, by microscope, by chemical analysis, and other means. This work was done on a small experimental cupola. Figure 3, illustrates the melting conditions found.

Similar work was performed by Rambush and Taylor with a fully operating 48-inch diameter commercial cupola. This was reported in the *Foundry Trade Journal*, Nov. 8, 1945.[3] Figure 3 and Table 4 show some of the conditions found. Here are some of the facts revealed in these studies:

1. "However carefully the charge materials are placed in a cupola in relation to one another, their relative position is not maintained during the descent of the charge." Uneven charging makes matters even worse.
2. "The shape and size of the metallic pieces in the cupola charge are dominant factors in governing their manner of descent." Long pieces, especially if relatively thin, upend on descent. So a long piece of scrap can actually be part of two charges near the melting zone.
3. "The rate of complete melting for the different metallic constituents is mainly governed by their shape and weight, as well as their relative melting temperature." Heavy and chunky pieces can descend far into the bed, or well, before completely melting.
4. Steel, of a given size, takes longer to melt. Therefore it melts down lower in the bed, while pig iron and scrap from charges above are already melting and passing by. Melting range temperatures for the different constituents are as follows:

1—Pig Iron	2050 F. to 2200 F.
2—Cast Iron	2100 F. to 2240 F.
3—Steel (0.58 Carbon)	2400 F. to 2650 F.

These figures show a spread of 450 F. for complete melting.

In the small cupola test, pig iron started melting 24 inches above the tuyeres and steel finished melting 15 inches above the tuyeres. In the larger cupola, solid steel pieces were found about 12 inches above the tuyeres while no cast iron was found lower than 30 inches from the tuyeres. This is a spread of 18 inches. Balanced proportions of each would represent a further spread.

In addition, charges with higher percentages of steel (10 per cent was used) could show even greater spread of consituents; it was shown that steel was assisted in melting by being washed away by drops of molten cast iron and pig iron from above. Lower percentages of iron in the charge would reduce the washing action.

5. It was shown that the coke, although evenly sized to start with, was progressively reduced in size from top to bottom, and outside to inside. The first greatest change occurred near the top of the coke bed. Apparently small or thin scrap could slip through the openings between the larger coke more readily.

Table 2.—Class 50 Iron Followed By Class 30 Iron

Type of Iron	Sample No.	% T. C.	% Si 2	% Steel
Alloy				
Hi-Strength	1	3.11	1.82	30
"	2	3.07	1.93	30
Transition	3	3.24	1.94	25
"	4	3.33	2.07	25
Soft	5	3.34	2.17	17½
"	6	3.33	2.22	17½
"	7	3.30	2.27	17½

1. 54" dia. cupola, 1700 lb. charges, 64" initial bed
2. These are final silicons, after additions
3. Blast pressure average—18 oz.
   Blast volume average—4200 cfm.
4. Melt rate 10 T/hr., 245 lb. coke splits, front slagging spout, 2790°F spout temperature, 1700 lb. ladles

Table 3.—Class 35 Iron Followed By Class 25 Iron

Type of Iron	Ladle No.	Am't Tapped	% T. C.	% Si	% Steel
Class 35	114	730	3.28	1.99	20
"	115	720			
"	116	770	3.25	2.01	
"	117	820			
Transition	118	800	3.25	2.19	
Class 25	119	760			10
"	120	750	3.35	2.43	
"	121	810			
"	122	670	3.32	2.43	

1. 40" dia. cupola, 1000 lb. charges, 105 lb. coke splits
2. 570° F hot blast, 3000 cfm., 2820° F avg. tap temperature
3. 6 T/hr. melt rate, 4 min. taps, rear slagging

6. "Where different types of metal are to be produced during the day's heat, the influence on dilution caused by the factors referred to . . . are of great importance."

It is also helpful to refer to a report in the AFS TRANSACTIONS —(1954), by Carter and Carson, "Some Variables in Acid Cupola Melting."[4] The authors show the effects of coke size, coke amount, air volume, and size and shape of steel scrap on the cupola melting rate and final analysis of the iron.

In regards to coke size, either excessively small or large coke gave lower carbon. Highest carbons resulted with coke of a proper size for the cupola involved. Increasing the amount of coke raised the resulting carbon level in the iron, as expected, and melt rate decreased.

Increased air blast volumes increased the melt rate but decreased the carbon only slightly, while silicon loss went up considerably. Medium section size steel gave higher carbon pickup; heavy section steel slightly less; and very thin steel gave lower carbons, higher sulphur, high silicon losses, and faster melting rates.

By making use of the above information and other knowledge, one realizes that several things can be done to assist in changing over from one type of iron to another.

1. High blast rates and pressures in general cause a greater melting zone spread. It would therefore help to run a lower blast rate to narrow the melt zone if sufficient air blast penetration is maintained. Incidentally, hot blast helps to accomplish this, but also lowers the melt zone.

2. The last two or three charges of the original iron can be selected to consist of uniformly smaller pieces of all metallic constituents so that they melt faster and more uniformly. The first charge or two of the new iron could have uniformly heavier and chunkier pieces to slow down the melting rate of the new mix.

3. Small coke can be used for the split or double split between the two irons and perhaps the next charge thereafter, if sufficient blower pressure capacity is available. This will help physically to keep the charges apart in descent. The small coke should also delay the start of melting of the new

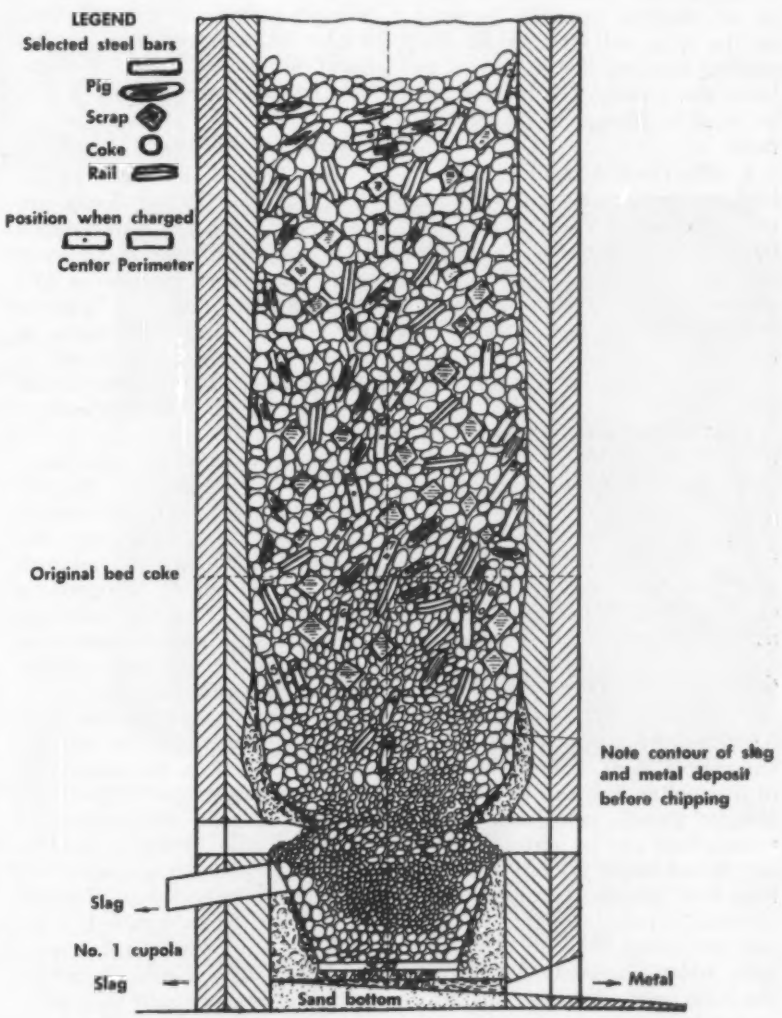


Fig. 3—Graphic representation of conditions during a blow.

Table 4.—Screen Tests on Coke After Removal

Location of Coke Layer in Feet below Sill of Charging Door.	Total Weight in lbs.	Over 4 in. Per cent.	Over 3 in. Per cent.	Over 2 in. Per cent.	Over 1½ in. Per cent.	Below 1½ in. Per cent.	Ash Content. Per cent.
2 ft. to 4 ft.	360	79.1	16.3	3.6	0.6	0.3	...
4 ft. to 6 ft.	372	64.4	29.0	5.0	0.8	0.8	...
6 ft. to 8 ft.	457	48.6	36.7	11.6	1.7	1.4	...
8 ft. to 10 ft.	574	36.2	46.3	10.5	3.5	3.5	...
10 ft. to 12 ft. 3 in.	688	33.1	47.0	10.9	2.8	6.2	10.6
12 ft. 3 in. to 14 ft. 6 in.	1,372	20.7	36.8	16.8	6.8	19.9	10.0
In front of tuyeres	198	3.5	20.2	31.3	10.1	34.9	12.7
Below tuyeres	142	0.0	10.6	22.5	10.6	56.3	14.1

iron. Carter reports "first metal drops" in five minutes for a cupola started and operated with 5-inch coke, but 15 minutes with 1 to 2-inch coke, for a 23-inch cupola.

4. Increase bed height and coke to iron percentage if you desire to raise the carbon on the new iron. Use leaner ratios if you want to lower the carbon. A "low-carbon" malleable iron type of coke of higher ash content can also be used on the split and some or all succeeding charges, if it is desired to lower the carbon. The reverse can be used to change to higher carbons.

5. When only a small amount of high carbon iron is required, run it at the start of the heat if possible. The first part of the cupola heat is almost invariably higher in carbon. If high carbon iron is run at the end of the heat, extra coke, limestone, and more complete slag removal prior to the new iron will help.

Most of the above steps are simple and inexpensive. Use them to assist in changing over from one iron to another, if more nearly complete separation is desired. Also, level and uniform charging, by hand or with the proper type charging bucket, is important in cupola operations at all times.

Change the Analysis in the Ladle

In addition to the methods outlined for changing the analysis in the cupola itself, ladle treatments of the molten iron can be utilized. Besides purely inoculating additions, alloys can be added to various ladles while filling with the base iron. Silicon, chromium, nickel, molybdenum, copper, vanadium, and other elements are regularly added. Amounts depend on the ladle batch size, the initial iron temperature, and the final temperature allowable from the pouring standpoint. Adding up to 2 per cent total of alloy by gross weight, and sometimes up to 3 per cent are common practice. Preheating or melting the alloys in another furnace prior to ladle addition is growing in popularity. Exothermic alloys are also available to reduce temperature losses when adding large amounts of some alloys, although excessive slag is a factor.

Ladle analysis can also be changed by injection methods. Some foundries are regularly injecting carbon in the ladle on a daily basis to produce a softer grade of iron whenever desired from their regular medium or high-strength base iron production. Better control and flexibility in the melting and pouring operations result. Total carbon can be raised from a 3.25 per cent base to 3.55 per cent total carbon final on a 1.75 per cent silicon iron in a matter of minutes. Recovery reaches about 40 per cent with a temperature loss of approximately 100 F.

Injection Techniques

The efficiency and rate of carbon pickup are higher with lower carbon base irons and lower silicon irons. Additional results and information have been reported in AFS TRANSACTIONS (1955) by Spangler and Schneidewind.[5] Continuous injection in a forehearth, or well in the spout, can give higher carbon recoveries and less temperature loss.

Sulphur removal by injection is growing in popularity. Sulphur can be more readily reduced to low levels and in a shorter time than with conventional forehearth or ladle treatment. Temperature loss again is a factor. Although with hot-blast cupola operations and hotter iron it is not necessarily a limiting consideration.

Removal of carbon in the ladle with oxygen for cast iron foundry use has not been too successful. With iron at a temperature of 2800 F., or over, and development of special techniques and special ladles or vessels, this probably will be applied in the future. Temperature must be maintained, especially at the metal-oxygen interface. Also silica should be present in the refractory and readily available. This reduces silicon losses and probably iron losses when fast carbon removal rates are involved.

Another smaller auxiliary furnace, such as an electric arc furnace, in conjunction with the cupola, can be used to change the analysis of a portion of the metal. A few shops run a batch-type cupola operation by starting and stopping the cupola repeatedly. Each batch is treated in an electric-arc furnace to make several different grades of iron.

Other shops duplex all the iron through the auxiliary furnace on a continuous basis. Additions of steel or use of oxidizing conditions reduce the carbon. Small or large amounts of alloy can be added. Pig iron additions will raise carbon a small amount. Carbon can also be raised by injection in the furnace. However, it is probably more convenient to tap hot and inject in the ladle. Most changes are made by simple dilution with steel or pig, or by addition of alloys.

Some foundries use a gas or oil-fired reverberatory type of furnace somewhat similar to those used for non-ferrous melting. Fairly high carbon and silicon losses usually result when using these furnaces for cold-melting cast iron. Gas firing usually gives greater carbon losses than does oil. To attain higher temperatures and speed and less carbon loss, preheat the air. Also water-cool the throat, or choke-point, to maintain its accuracy and life and accurate fuel to air adjustments.

Induction furnaces usually operate with cold metal charges instead of molten metal charges. They are normally used for more expensive alloys than regular grades of iron. The line-frequency type induction furnace may popularize this.

Small air furnaces of the powdered-coal-fired malleable iron type have been used for duplexing special irons.

Altogether there are quite a few ways open to the foundry for changing types of iron in the course of a single cupola heat—either inside or outside the cupola. The types of irons to be made, materials available, and production and economic conditions will determine the most useful methods for a particular situation.

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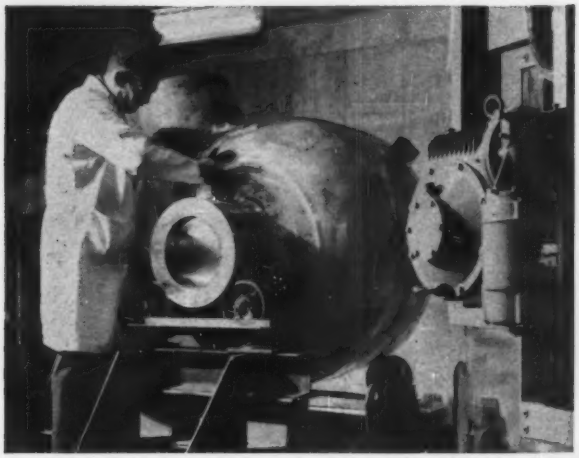

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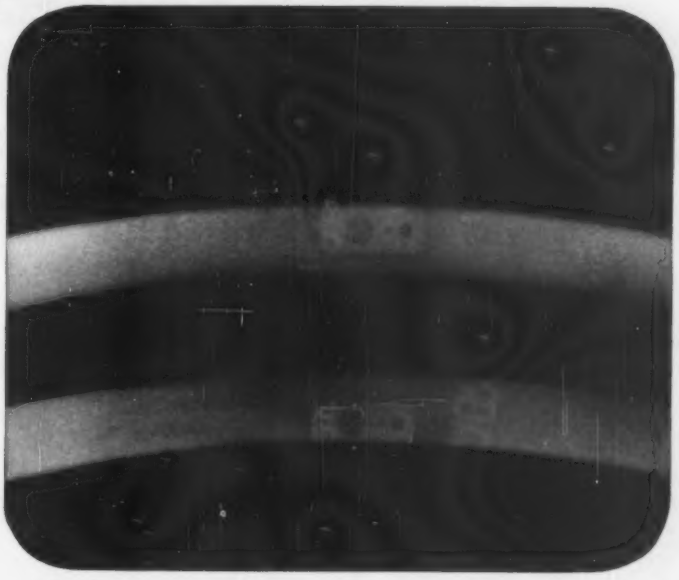

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Circle No. 127, pages 157-158

Castings Congress Papers

S. C. Massari

New techniques in wood patternmaking is foremost article in the Castings Congress Papers, this month. Other papers: Centrifugally-cast steel tubing, solidification of Aluminum castings and copper alloys, and a summary of metals solidification. Also designed to present technology for profit are papers on developments in magnesium castings, an evaluation of fabrication methods and dephosphorizing-desulfurizing steels.

TECHNICAL HIGHLIGHTS

New Patternmaking Materials .....*p 53*
New techniques in wood patternmaking appear likely through a carvable epoxy available in plank or paste form. Advantages claimed are: elimination of grain or knots; uniform swelling; less shrinkage; higher heat distortion point; flame resistance; and elimination of aging and drying. Epoxy can be worked with standard wookworking equipment.

Centrifugally Cast Steel Tubing .....*p 56*
Certain advantages in centrifugally casting steel tubing have been realized using considerably higher speeds with the elimination of the usual hot tearing and cracking problems. In production, 20-ft. flasks are lined with a flowable ceramic type refractory and compacted by spinning. The tube diameter can be produced to any given size depending only on the volume of the lining mix.

Solidification of Aluminum Castings .....*p 66*
Pouring a dozen or more alloys daily in aluminum foundries is not unusual. Each alloy behaves slightly different upon solidification. Principles underlying solidification behavior of many commercial casting alloys may be understood through a study of aluminum-4.5 per cent copper alloy.

Solidification of Copper Alloys .....*p 81*
Commonly cast copper alloys may be divided into two groups according to their method of solidification. One freezes by the mechanism of skin or shell formation, the other by a pasty or mushy manner. An understanding of the fundamentals involved in solidification will aid in eliminating many non-ferrous casting problems.

Metals Solidification Summary .....*p 87*
Theory and practice are linked in the summary of the preceding papers on the solidification of aluminum and copper alloys. Obtaining a desirable grain structure involves a careful selection of mold material, mold density, pouring temperature, selection and location of exothermic compounds, and use of foreign body nuclei.

Developments in Magnesium Castings .....*p 92*
Use of the latest technological developments and extensions of older technology has greatly broadened the field for magnesium castings. New alloys allow higher temperature applications and higher strength applications at both room and elevated temperatures. Increasingly more intricate, high quality castings are being produced with more versatile physical properties.

Fabrication Methods Evaluation .....*p 97*
Satisfaction with the end product involves an evaluation of the new materials and processes, coupled with the proper use of the best materials and manufacturing processes. Author Frantzreb appraises the status of the various competitive methods of fabrication such as forging, shaping, machining, and joining.

Dephosphorizing and Desulfurizing Steels ....*p 107*
Formulas have been developed to relate laboratory investigations and plant-scale activities in the study of the kinetics of desphosphorization and desulfurization during the production of steel in a 6½ ton basic-electric arc furnace.

The AFS Casting Congress papers are the most authoritative technical information available to the metalcasting industry. Over 100 papers were prepared by close to 250 authors and presented at the 1960 Congress in Philadelphia, May 9-13. Papers receive preview publication in MODERN CASTINGS and then are bound into the annual volume of AFS TRANSACTIONS for permanent reference. All papers have been approved by the appropriate Program and Papers Committee of the sponsoring AFS Technical Division. They are then edited by AFS staff members C. R. McNeill and M. C. Hansen. Written discussion of these papers will be welcome.

NEW MATERIALS FOR WOOD PATTERNMAKING

by Robert LeMaster

ABSTRACT

A new development in the wood patternmaking industry is described by the author. The new material is a carvable epoxy which is available in either plank or paste form. The advantages of this patternmaking material are given by the author, and include — no grain or knots; uniform swelling, approximately 10 per cent that of mahogany; less shrinkage; higher heat distortion point; flame resistance; nonabrasive; and no aging or drying needed. Some of the disadvantages are: higher cost and slight tendency to dull tools more than natural woods. Application techniques of the paste form of this material are presented.

INTRODUCTION

During recent years metal and plastic phases of patternmaking have seen countless advances in techniques, processes and equipment. Much of this has been brought about by parallel advances in foundry technology. Considerable publicity has followed these developments and focused attention toward metal and plastic patterns. Although wood patternmaking has progressed slightly, it has been forced into a realm of mediocrity by a lack of new developments. Wood patternmaking represents the last frontier of true craftsmanship in the foundry industry. Through centuries little changes have resulted because such handwork is necessary for obtaining an original shape. Methods of today vary little from those our grandfathers used.

NEW PLASTICS

Recently developed plastics may prove to be a major time saver and alter many construction methods currently being used. For lack of a better name I will refer to this new plastic as carvable epoxy. It is available in plank (Fig. 1) and paste form. Both forms are basically a formulation of an epoxy resin and phenolic micro balloons. It can be worked with any woodworking equipment or hand tools. Its weight, appearance and hardness are comparable to mahogany.

Carvable epoxy in its plank form represents a synthetic board. Ten years ago it would have been called impossible; but as the improbable things become reality the word impossible loses much of its meaning. A synthetic board has several advantages over nature's best efforts at producing wood.

1) It has no grain; much of today's construction is involved in proper placement of grain to avoid warping, distortion and loss of dimensional accuracy. Segmenting and laminating are unnecessary.
2) No grain means no knots. Plastic planking is

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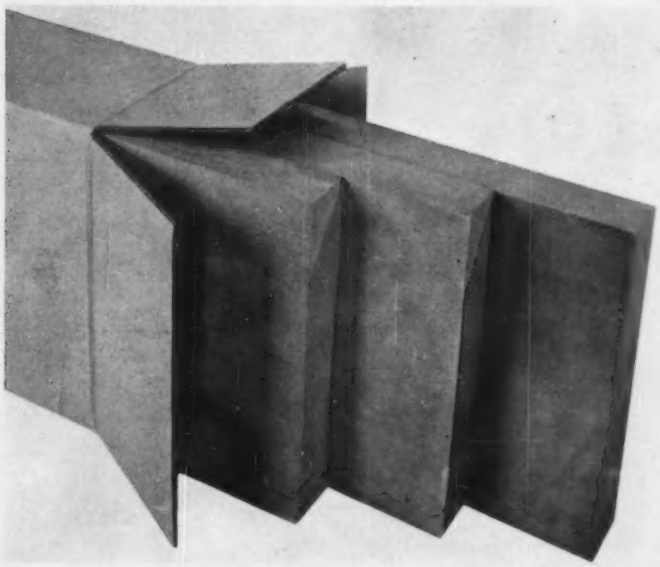

Fig. 1 — Packaged plastic plank ready for use.

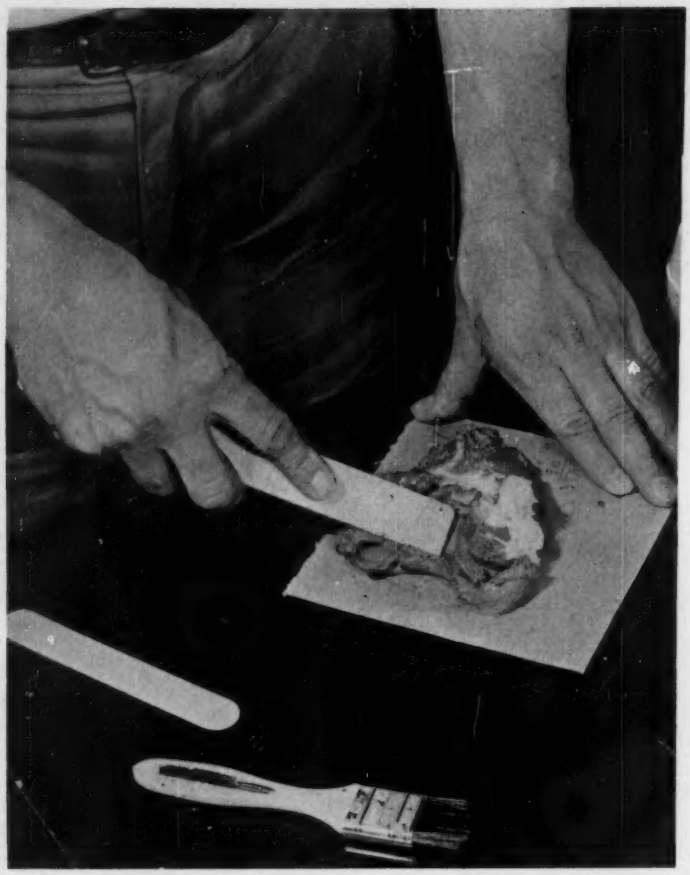

Fig. 2 — Proper mixing procedure and shows viscosity of the paste form of carvable epoxy.

100 per cent usable. Even scraps may be assembled into usable blocks. Every piece is uniform in texture.

3) Swelling under adverse humidity conditions is approximately 10 per cent that of mahogany. Any swelling is uniform in all directions.
4) Shrinkage after 72 hr at 100 F is only 0.001/ft compared to 0.035/ft on mahogany tested.
5) Heat distortion point is higher than mahogany so no warping of the plank can occur during sawing. Only minor stress relieving causes slight bowing of long lengths.
6) Plastic planking is flame resistant and will not support combustion after the flame source is removed.
7) Screws and nails hold and tapped holes will not strip loose. Lack of grain minimizes splitting tendencies.
8) It contains no abrasive materials. It does, however, dull tools more than conventional pattern woods.
9) This synthetic wood requires no aging or drying for moisture elimination as its manufacturing process and natural properties resist moisture penetration.
10) To hold down construction costs, a bulkhead of plastic planking may be built onto with conventional wood. This type construction cuts down on high material costs but eliminates warpage and shrinkage possibilities on intricate patterns. This construction method offers good insurance against dimensional movement.
11) Conventional white glue provides satisfactory bonding strength.

Plastic planking is available in several sizes by various formulators, most lengths are restricted to 6 ft; thicknesses range up to 2½-in. Its cost in small quantities is about $3.50 to $4.00/board ft.

TESTS AND DISADVANTAGES

Although the advantages of this synthetic wood seem unlimited, it is only after the disadvantages are recognized that proper applications can be realized. Its major drawback to universal acceptance will be its high cost and slight tendency to dull tools more than nature's woods. Although numerous test results are available from formulators, they mean little to anyone except in the comparison of competitive materials. Most pattern shops would resort to some sort of unscientific tests as undertaken by the author's company.

Hammer tests proved surprising. Plastic planking does not seem to dent as much as mahogany. Sharp edges resist hammer blows better than expected. Splintering was pronounced with mahogany. Severe blows did flake large areas loose, but the material exhibited surprising toughness. Sand blast tests gave some idea of what wear resistance to expect. This mate-

rial was developed as a master model material and should find few applications where wear resistance is required. Blasting of the sample indicated that plastic plank eroded slightly more than mahogany.

The paste form of this carvable epoxy is the most versatile material ever introduced to wood patternmaking. Its applications are numerous, and are limited only by a patternmaker's ingenuity and desire to save time and money. The original desire was to find a substitute for plastic wood. It had to be carvable, trowelable, exhibit good adhesion, have low shrinkage and harden in a short time. Carvable epoxy not only filled these requirements, but proved even more versatile by exhibiting good dimensional stability. It shrinks about 0.015 to 0.020/ft. The pot life is 15 min.

EPOXY PASTE USES

As a fillet material, it has no equal in complex shapes. Leather fillets are still more economical in straight areas. The paste is worked into corners, with a spatula or fillet ball, then ironed to shape with a heated fillet ball. If the squeezed-out excess is removed before hardening, the result is a smooth, accurate, noncollapsing fillet with sufficient strength and adhesion to greatly add to the strength of the equipment.

The paste was also utilized for a squashing technique to avoid chalking-in. When adding bosses, core prints, ribs, etc., to compound shapes, this paste is applied to a rough sawn block and squeezed against a waxed contour in the approximate position desired. After hardening, layout lines are transferred, then it is knocked apart and worked back down to shape. Since the paste area has cast itself against the contour, relocation in the exact spot is assured. This technique offers many variables but the simplicity of it never varies.

The trowelable properties of the paste have been used to repair worn areas on wood patterns (Figs. 2 and 3). For the construction of master patterns the author's company has built-up or flared-in complex shapes over a core plug. After troweling to a desired wall thickness, ribbing is added to complete the master.

A quick mold or core box can be produced by simply troweling over a master. The exothermic heat created is quite low so that 1 in. thicknesses provide no problems. This troweling method can produce a take-off equal to a laminated epoxy with less material and labor cost. A troweled mold can be backed with plaster even before the epoxy paste has hardened since the presence of moisture causes no boiling. Such a plaster backed paste mold possesses little chemical bond, so anchors or mechanical locks should be provided between the plaster and the plastic.

The practice of developing wall thicknesses over a cylinder head port slug previously required the shaving of a plaster shell to exact dimension. The plaster was messy, damaged tools and was very fragile. Carvable epoxy now provides a means of accomplishing the same with fewer problems.

METAL SHOP USES

Although the primary interests are centered in the wood pattern shop, this material has found its way into the metal shop. The author's company makes many checking slugs out of shell core boxes. These slugs are cheaper to make than plasters, less messy, and provide an accurate reproduction of completed boxes. The company's customers appreciate the interest in providing them with such quality equipment.

The companion materials, epoxy planking and epoxy paste, form a new approach that may well shape new techniques in wood patternmaking.

Fig. 3 — Making a plastic mold with paste epoxy. Mixed paste is troweled and brushed over contour previously warmed by heat lamp.

CENTRIFUGALLY CAST STEEL TUBING PROPERTIES AND APPLICATIONS

by E. D. McCauley

ABSTRACT

The author refers briefly to the successful application of centrifugal castings in industry and outlines the conventional production methods, the advantages and disadvantages related to these methods. The report describes large scale production experiences with a new method of molding developed to incorporate the advantages of both of the leading methods and to eliminate the disadvantages of each. Certain advantages have been realized in utilizing speeds considerably higher than have been conventional, and without encountering the usual hot tearing and cracking problem previously associated with high speeds.

Engineering designs are described where the high quality of this type of production has been utilized. Physical properties are reported and compared with those typical to other methods of production. Quality control and inspection methods necessary in maintaining a desirable performance level are outlined.

INTRODUCTION

The development of centrifugal castings, the advantages this type casting offers in industrial applications and the basic principles of the conventional methods of production have been described and recorded in the journals of the American Foundrymen's Society SYMPOSIUM ON CENTRIFUGAL CASTINGS (1944).[1] The present report concerns itself chiefly with the latest method of large scale manufacture of centrifugal tubing, the properties obtained from tubing cast by this method and the subsequent fabrication into component parts which supply industrial design requirements.

The observations and conclusions offered in this paper are based on experiences at the author's plant with large volumes of centrifugal production in permanent molds, sand rammed molds and molds produced by a more recent method.

The normal demand on the average centrifugal steel production unit is quite diversified requiring maximum versatility in casting size (length, diameter and thickness) and metal composition. The major producing units have heretofore utilized two principal methods of manufacture—production through the use of permanent molds, and production through the use of sand lined molds. There are apparent advantages and disadvantages in both methods which, if considered briefly, can be summarized.

1. Permanent Mold Methods.
   Advantages.
   1) Rapid solidification resulting in fine grain and uniform distribution of inclusions.
   2) High production per casting machine due to faster solidification.
   3) Close control of dimensional tolerances due to the rigidity of the mold.
   Disadvantages.
   1) High mold cost due to fixed size range and short mold life expectancy.
   2) Difficulties experienced in combating hot tearing due to the critical balance required between speed and casting thicknesses.
   3) Difficulties experienced in controlling lapping tendency due to the chilling nature of the mold.
   4) Difficulties experienced from spalling of the mold facing.
2. Sand Lined Mold Castings.
   Advantages.
   1) Lower mold cost due to a practically unlimited life expectancy of flask equipment.
   2) More suited to longer cast lengths due to the reduced chilling of the molten metal flowing longitudinally over the mold and the reduced thermal gradients in the mold.
   3) Generally smoother cast surfaces requiring less machining stock.
   4) Easier control of hot tearing or cracking due to the different mode of solidification.
   Disadvantages.
   1) Difficulties experienced in the control of ramming density, drying uniformity and inclusion formation.
   2) Difficulties encountered from mold scabbing and erosion.
   3) Difficulties arising from mold swells and mold eccentricity.

From the demand for both type castings in similar fields of application, both methods of production have been successful in supplying industrial requirements. The properties and applications of the castings described herein represent those obtained from a new method of production.

CERAMIC MOLD METHOD

After several years of research and development at the author's company, a new method of ceramic molding has been designed to incorporate the advantages and to eliminate the disadvantages of each of the previously mentioned methods. Such a method offers a baked ceramic type mold for maximum life expectancy of mold equipment, maximum versatility in size (length and diameter) without customary

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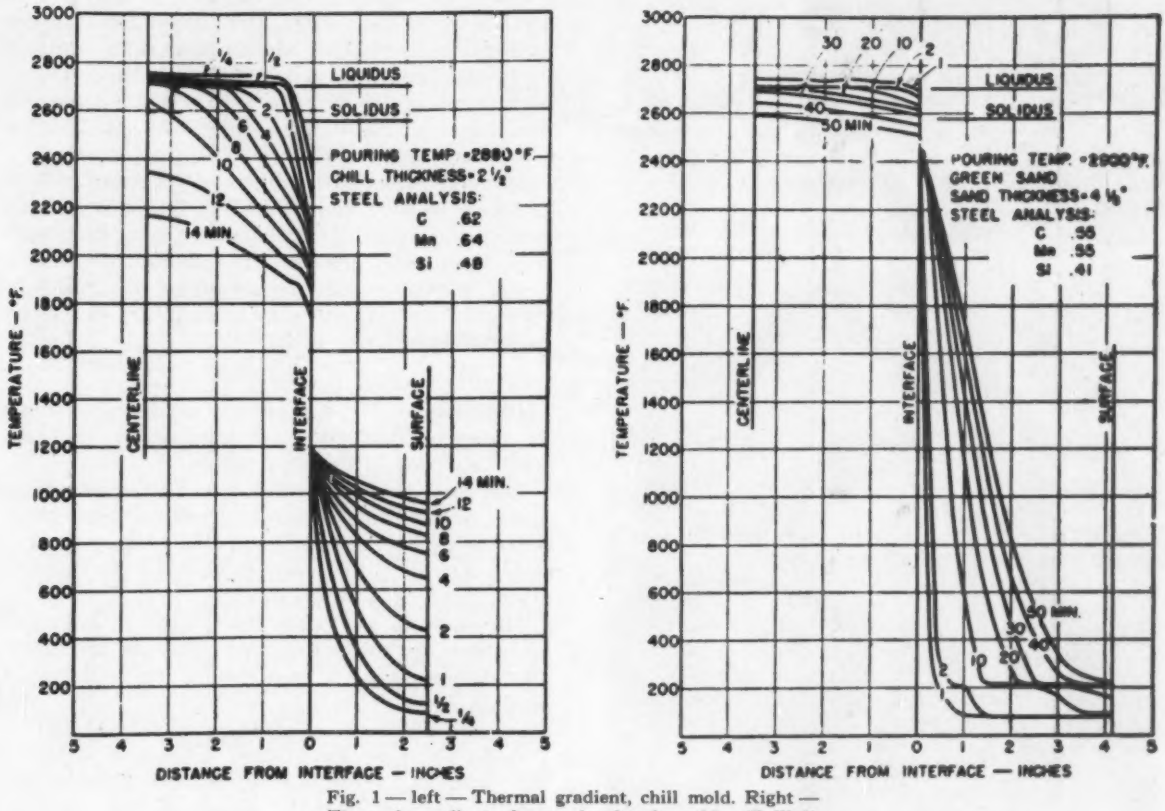


Fig. 1 — left — Thermal gradient, chill mold. Right — Thermal gradient, heavy insulated mold. (Pellini)

equipment investment, high mold density and uniformity with positive concentricity control. Automatic weighing, pouring and speed control are also used at the casting machines to reduce casting variables.

Theory

Thick wall centrifugal steel castings have presented certain production problems arising from the intricate balance required between two opposing forces: metal contraction versus centrifugal force (speed). Wallace,[2] in his work with centrifugally cast steel gun barrels at Watertown Arsenal, developed various formulas and theories balancing these forces against solidifying skin strengths in an effort to control hot tearing in centrifugal castings produced on metal molds.

Pellini[3] has demonstrated from the analogue studies of Paschkis[4] the thermal gradients expected across solidifying wall sections cast against chill molds and against sand molds (Fig. 1).

It follows that solid contraction accompanies temperature drop, thus giving rise to the problem of skin strength versus hoop stress from centrifugal force in a permanent mold casting. In this case, solid contraction is encountered prior to complete solidification necessitating the continuation of the applied spinning force until complete solidification.

Unlike this phenomenon, castings in sand molds do not enter solid contraction until the solidus temperature is more uniform across the wall thus minimizing the stresses arising from hoop tension prior to complete solidification. With metal mold centrifugal castings, as solidification contraction of the metal occurs there is often, at the same time, an expansion of the mold due to heat absorbed from the molten metal. This can result in an unsupported semi-solid casting with hot tearing or cracking from hoop stresses developed during spinning.

With a dense ceramic mold in a rigid metal flask, however, expansion of the mold material tends to result in a contraction of the mold inside diameter. This reinforces the contracting casting and provides support against hot tearing or cracking. Thus, contrary to certain theories concerning peripheral speeds, extremely high speeds have been utilized in the ceramic process without encountering hot tearing problems.

Centrifugal Force Effect

Zeuhlke[5] has indicated in his studies of centrifugal castings that the degree of metal cleanliness is a function of specific gravity and force. Assuming constant viscosity conditions, the degree of metal cleanliness in a centrifugal casting is therefore dependent on the magnitude of the centrifugal force. Thick walled carbon steel castings have been produced by this method with casting speeds developing forces as high as 150 times gravity without cracking or hot tearing (Fig. 2).

Due to the fact that the less dense materials, such

Fig. 2 — Thick wall centrifugal castings.

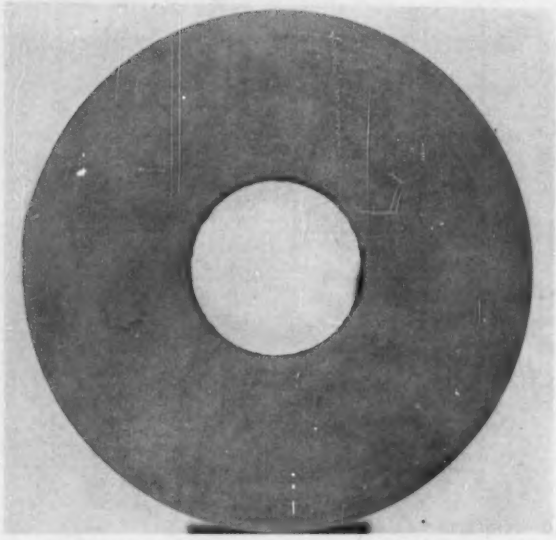


Fig. 3 — Macroetch of 4½-in. thick centrifugal casting.

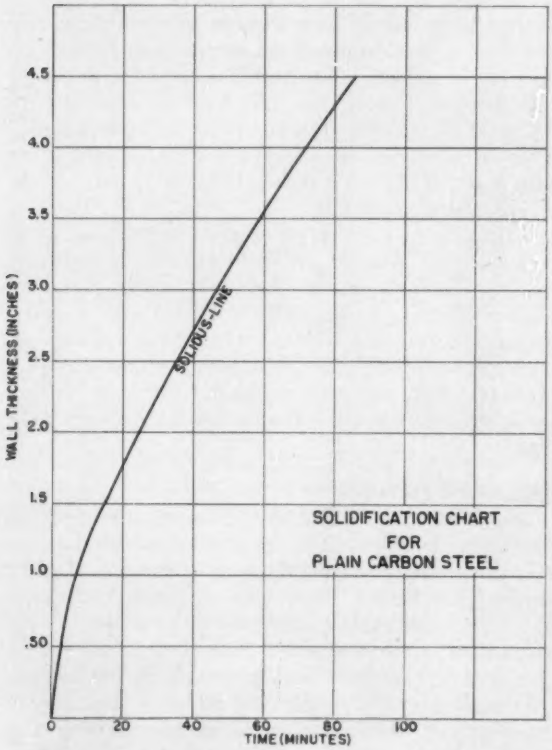


Fig. 4 — Solidification curve carbon steel tubing centrifugally cast in heavy insulated mold.

as dross and slag inclusions, accumulate near the inside surface of the casting, it is important that this condition be considered when tubing is to be bored for applications, such as hydraulic cylinders. It is of further importance that the tube wall be dense and sound after boring. Positive directional solidification is necessary to establish such a desired condition.

If directional solidification is not present, midwall shrinkage may be encountered as is found in some static castings which experience heat losses from both sides of the wall section. The macroetched section in Fig. 3 demonstrates the soundness which may be expected from a 4½-in. thick casting cast on a heavy insulated ceramic type mold.

Cooling Curves

The curve in Fig. 4 shows the solidification times for different thicknesses of centrifugally cast steel tubes produced in this type mold.

This curve was established from numerous cooling curves representing various diameters and thicknesses of carbon steel tubes cast in heavy refractory molds. A typical curve used to establish the relations shown in Fig. 4 is shown in Fig. 5.

The curve in Fig. 4 has been found to hold true for various cast thicknesses from ⅜-in. through 4½-in. This demonstrates the constancy of the solidification mechanism.

Certain additional procedures as pointed out by Donoho,[6] may be used to aid directional solidification, such as controlled pouring rates to assure progressive freezing from the outside as the section is built up, the use of exothermic or insulating materials applied to the inside surface to retard freezing from the inside, closing the mold at each end to exclude air currents and reduce radiation loss on the interior surface and the application of high spinning speeds to produce maximum centrifugal force across the solidifying wall.

PRODUCTION METHODS

In order to obtain the advantages outlined above, definite production procedures for this new method of ceramic molding have been established. The 20 ft flasks in which the tubes are produced are lined with a flowable ceramic type refractory and spun compacted, in order to produce a lining density approximately 20 per cent greater than that obtained in conventional sand rammed molds. As can be seen, the mold diameter (consequently the tube diameter) can be produced to any given size depending only on the volume of lining mix.

It has been found that if a graded particle size of refractory mix is used, the finer and more refractory material will accumulate during compaction at the inside surface (Fig. 6). This is highly advantageous in that an integrally formed mold facing is produced, thus avoiding the occurrence of separate layers, the inner layer being subject to flaking or spalling as may be often found in washed or spray faced molds.

The larger particles of the mix accumulate towards the interface between the flask and the lining. This has been found to be advantageous in venting mold gases during the baking and casting operation.

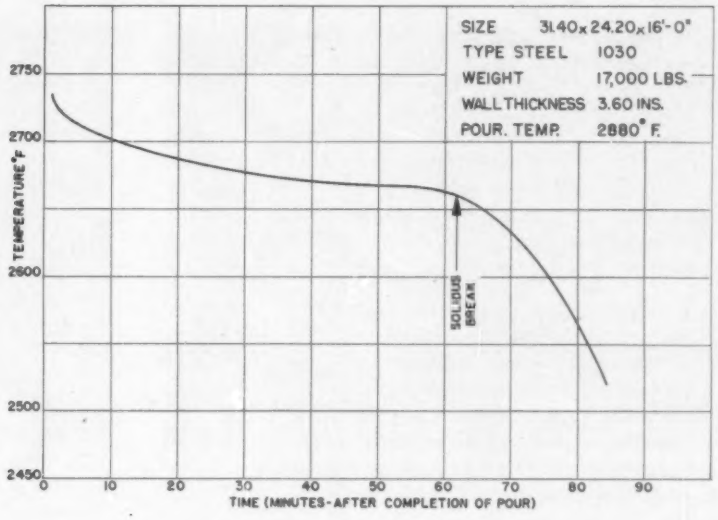


Fig. 5 — Typical cooling curve of centrifugal tube cast in heavy refractory mold.

Perfect concentricity in the flask/mold system is obtained, since the horizontal spinning axis is the same for both molding and casting. A routine method of varying the location of a stop-off plate has been devised to produce any given length within the 20 ft mold with little additional cost. After the lining operation the molds are baked in gas heated, automatically controlled, recirculating type furnaces for a predetermined length of time. Thus, complete drying and bonding of the mold material is assured.

The casting operation is carried out by pouring from a hydraulically operated machine ladle through a pouring box and orifice which are located at one or both ends of the flask. Molds are warm when cast on to reduce any chilling effect and consequent tendency towards lapping. Pouring temperatures in the range of 150 F (66 C) above the liquidus temperature are used for most steels. Pouring weights are controlled by electronic scales mounted under the machine ladles with remote dials located convenient to the operator (Fig. 7).

Spinning speeds are determined in terms of "g's" or "times gravity."

$$g = \frac{N^2 D}{70{,}500}$$

Where g = units of acceleration due to gravity.
= 32.2 ft/sec/sec at standard conditions.
N = spinning speed, rpm.
D = diameter, in.

A different pattern of speeds is used for each size tube. The casting machine operation is programmed to vary spinning speeds in accordance with tube diameters and chemical compositions. Based on predetermined schedules, all speeds, speed changes and times are set up in push button controlled equipment which automatically carries the casting through the required cycle. Immediately after pouring is complete water sprays are directed over the flask for cooling.

After the casting operation is complete the tubes are stripped from the flask, inspected, heat treated (as required), machined, fabricated, tested and ship-

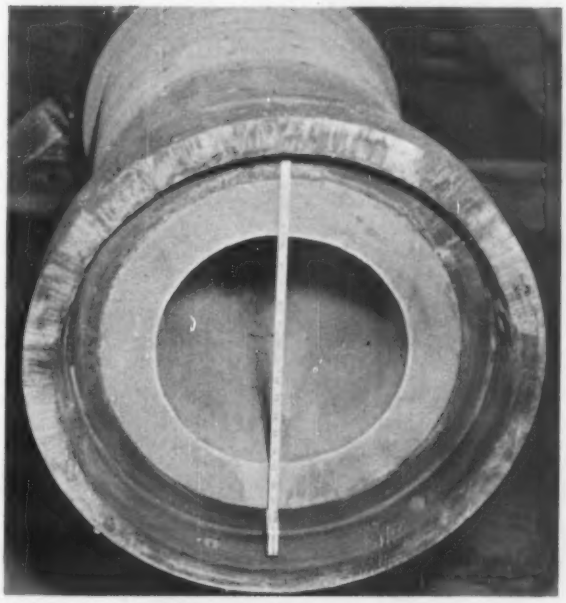


Fig. 6 — Ceramic mold ready for casting.

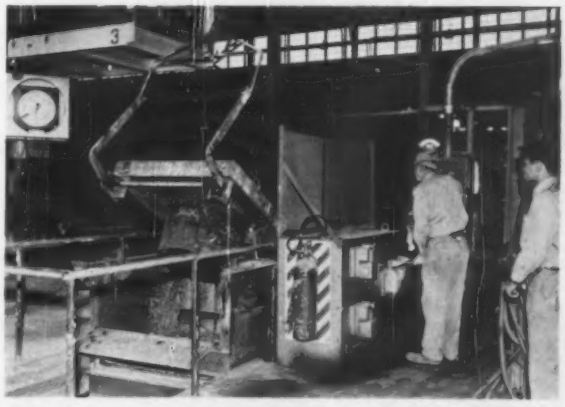


Fig. 7 — Pouring centrifugal tube.

ped. The ceramic mold material is removed from the flask, reprocessed and reused in producing other molds.

ENGINEERING APPLICATIONS

The economical application of centrifugally cast steel tubing has been used in many engineering designs. In comparison with other methods of production certain advantages have been realized. These are:

1) Flexibility in metal composition.
2) Flexibility in length, diameter and thickness.
3) High casting yields.
4) Nondirectional physical properties.
5) Desirable fabricating characteristics.
6) Superior machining characteristics.
7) Adaptability for various heat treatments.
8) High degree of mechanical integrity.

The most economical applications are those utilizing simple shapes where production volume does not permit special tooling and yields are highest. These applications conventionally resolve into true (horizontal spinning axis) centrifugal castings, cylindrical in shape. When local points in design require special configurations, advantages are realized in combining centrifugally cast tubing with static castings, plate or bars.

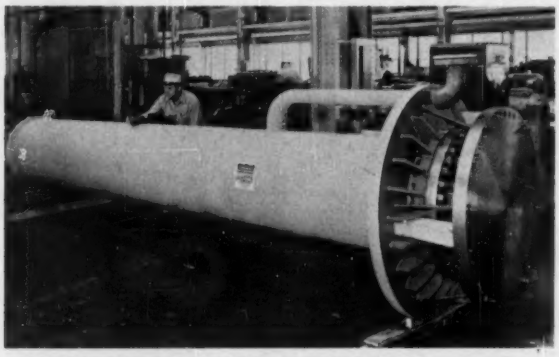


Fig. 8 — Assembled 31.50 in. cylinder and ram.

Fig. 9 — Automatic welding of cap to centrifugal cylinder.

A typical example of such a construction is illustrated in Figs. 8, 9 and 10. Figure 8 shows a completely fabricated, machined, assembled and tested cylinder and ram produced from centrifugal tubing, static castings and plate. Design requirements were such that light weight and high strength were desired. The cylinder was fabricated from centrifugal tubing 31.50 in. outside diameter x 29.50 in. inside diameter, sealed with a simple shaped static cap (Fig. 9), a 60 in. diameter plate and a statically cast end flange. The unit when complete was 19 ft long. Being a displacement type cylinder the inside diameter was finish bored. Full wall weldments were produced with automatic welding equipment.

The ram assembly is shown in Fig. 10, and was produced from 4130 steel heat treated to a 60,000 psi minimum yield strength. The finished part was made up of a static flange casting, centrifugal tubing 26.75 in. outside diameter x 21.75 in. inside diameter x 22 ft long and a statically cast cap. All weldments were made with automatic equipment using 1¼-per cent chromium – ½-per cent molybdenum deposits, stress relieved to 75,000 psi yield strength and gamma ray inspected to A.S.M.E. code requirements.

The completed unit weighed 22,000 lb and was tested to 750 psi for 30 min. Operation is in the vertical position with lateral thrust on the ram head at an extended stroke of 14 ft 8 in. Such operating condition demanded high strength.

Friction Type Ram

Other cylinders and rams are shown in Fig. 11. The rams in this case are centrifugal tubes 12 in. outside diameter x 8 in. inside diameter x 11 ft long sealed with plate at one end and fabricated to a statically cast head on the other end. Being a friction type ram, the head was overlayed with bronze by the inert gas automatic welding method and the body ground to a fine finish on the outside diameter. The cylinders were constructed from 1025 steel centrifugal tubing, statically cast weld necks at each end and plate for locating pads. These cylinders were cast 18.60 in. on the outside diameter and honed to a 32 micro-inch finish at a 16.019 in. inside diameter 12 ft long.

It is advantageous when producing for combination designs, as outlined above, to cast parts to be

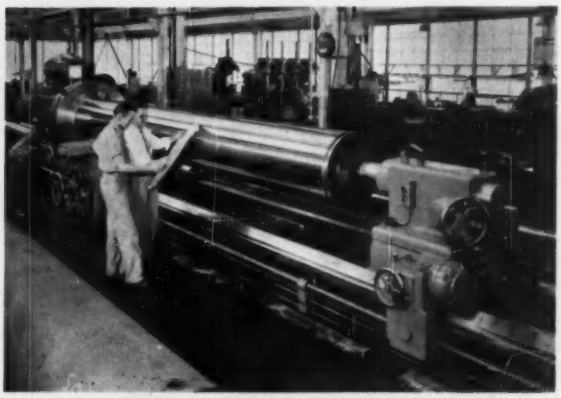


Fig. 10 — Finished surface of ram.

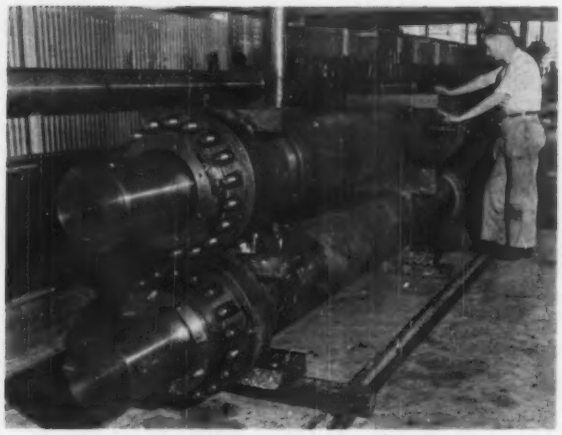


Fig. 11 — Fabricated steel cylinders and rams.

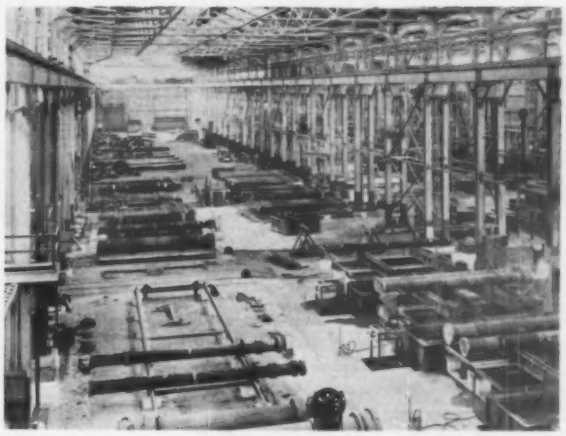


Fig. 12 — Centrifugal machines for 20 ft castings.

fabricated from the same heats. Figures 12 and 13 illustrate a centrifugal and static floor suitable for such an operation.

Figure 12 shows 20 ft long centrifugal casting machines located so that pouring is from the bay to the right (Fig. 13) which houses a static molding and pouring bay. Metal is tapped from 10,000 lb capacity arc furnaces (Fig. 14) into the pouring bay. Splits between the centrifugal machines and component static parts may be made as desired. Combinations of this nature are shown in Figs. 15 and 18.

Figure 15 shows a 31 ft 10⅛-in. long drive shaft fabricated from two static end flanges and 30.70 in. outside diameter x 26.00 in. inside diameter centrifugals. All material was produced from 4130 steel heat treated to 60,000 psi minimum yield strength, 100 per cent ultrasonically tested and welded under A.S.M.E. radiograph requirements. Fatigue had previously been experienced in carbon steel which indicated a requirement for higher strength materials. Since existing equipment had to be complemented, changes in dimensions in order to gain strength from an increase in section size could not be tolerated. Directional properties and high quality were of prime concern in the design of this 25,000 lb shafting in transmitting 30,000 horse power at 360 rpm.

Typical properties in four directions taken from centrifugal tubes produced on a heavy insulated ceramic mold are shown in Fig. 16. The uniform soundness of the wall section is indicated by the results of the tension tests and the nondirectional properties explained by the equiaxed grain orientation common to this method of production.

Fig. 13 — Static molding and pouring area.

Fig. 14 — Tapping 10,000 lb capacity arc furnace.

Wrought vs. Cast Steel

Fatigue properties and directionality of wrought and cast steels have been studied and summarized by Evans, Ebert and Briggs.[7] Figure 17 pictures the results of their findings, and shows that castings have equal properties in the longitudinal and transverse direction, whereas wrought materials show better properties in the longitudinal direction at the expense of lower properties in the transverse direction. Transverse properties are important in the design of

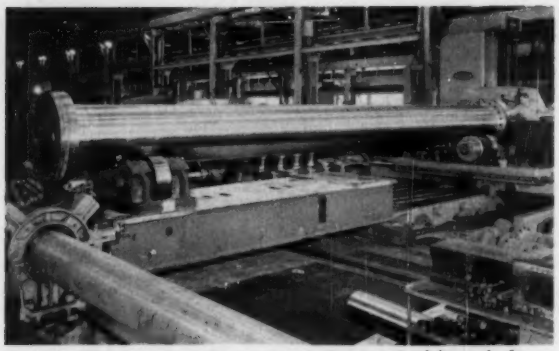


Fig. 15 — 30 in. diameter wind tunnel drive shaft.

cylinders, pressure vessels and shafting transmitting torque loads.

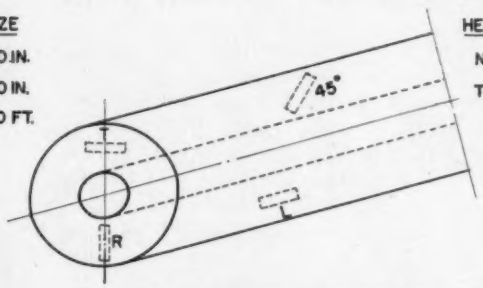
Physical properties realized in centrifugal castings are of interest in designing for high temperature and pressures. Figure 18 shows a combination of type 310 stainless steel centrifugal tubing and static end flanges designed to operate at elevated temperatures. These parts were fabricated into a pressure vessel machined to $34\frac{3}{16}$-in. outside diameter x $32\frac{3}{16}$-in. inside diameter x 28 ft long (approximately).

Further versatility of centrifugally cast steel tubing in industrial designs is indicated in Figs. 19, 20 and 21. Figure 19 shows the machining of a 10.25 in. diameter, 1.18 in. wall x 16 ft long trunnion assembly used in the Saturn missile transporter. In this application high strength and reduced weight were of chief

HEAT NUMBER	C	Mn.	P	S	Si.
401703	.262	.55	.028	.038	.61

CAST SIZE
O.D. 13.80 IN.
I.D. 4.50 IN.
LGTH. 20 FT.

HEAT TREATMENT
NORM. 1650° F
TEMP. 1150° F



	TENSILE psi.	YEILD psi.	%ELONG.	%RED. AREA
TRANSVERSE (T)	73,200	49,700	27.3	42.0
LONGITUDINAL (L)	71,500	47,700	27.5	35.8
45°	74,200	50,700	27.3	37.6
RADIAL (R)	74,700	45,900	36.9	57.0

Fig. 16 — Directional properties of centrifugally cast steel tube.

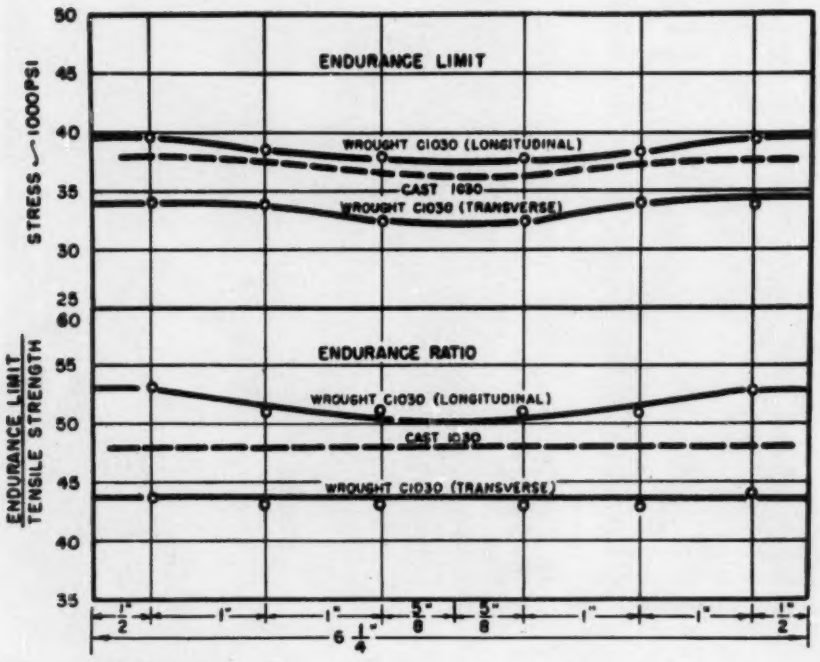


Fig. 17 — Comparison of properties — wrought and cast steel (Evans, Ebert and Briggs).

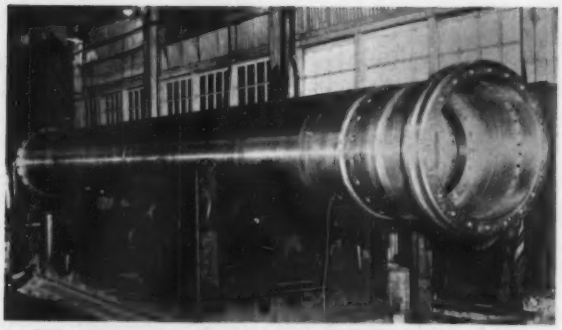


Fig. 18 — 30 in. diameter 10,000 lb stainless retort.

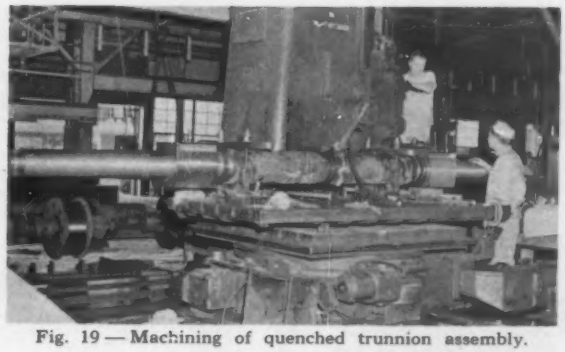


Fig. 19 — Machining of quenched trunnion assembly.

concern. Type 4130 centrifugals produced on ceramic type molds were water quenched and tempered to a required yield strength of 75,000 psi and fabricated with 4330 saddle blocks and 4130 solid forgings.

Figure 20 shows a 70 in. diameter 22 ft deep vertical quench tank capable of 4000 gallons/min flow which was used to impart the necessary strength demanded in this design. A vertical gas fired, automatically controlled annealing furnace is shown adjacent to the quench tank. These units are capable of normalizing, annealing, quenching and tempering 20,000 lb loads of 20 ft long tubing. Operation was designed for vertical suspension in order to maintain maximum straightness.

Figure 21 shows the final trunnion and beam assembly. Static walking beam castings of 4130 steel were assembled with the fabricated tube trunnion section. Extreme care was necessary in the fabrication of the trunnion assembly in order to select analyses, weld deposit, interpass and post-heat temperatures which would not adversely affect the physical properties of the quenched trunnion section. The centrifugal tube section was produced to meet the radiograph requirements of A.S.T.M. E-71 Class I with no repair welds allowed.

These tube sections were cast 10.50 in. outside diameter x 6.98 in. inside diameter and machined to a high surface finish at 10.25 in. outside diameter x 7.87 in. inside diameter indicating a 70 per cent yield.

Fig. 20 — 22 ft deep vertical quench and annealing furnace.

Balance Requirements

In rolls of certain types, balance and the economy of achieving balance is of concern. Figure 22 shows a 19,200 lb roll 35⅝-in. outside diameter x 34 ft 2 in. long produced from centrifugally cast steel tubing being finished to a 62 micro-inch surface on the outside diameter. Balance requirements were maintained with an as-cast inner surface. Due to the nature of the casting process concentricity of the castings is essential, since a condition of imbalance cannot be tolerated in the spinning process particularly in the speed ranges of 150 times gravity.

Centrifugal tubing can be cast from the full range of compositions in carbon steels, low alloy steels and high alloy heat and corrosion resisting steels, as well as alloy irons, ductile irons, Ni-resists, Ni-hards, etc. Molten metal is available from acid and basic arc furnaces, induction furnaces and acid or basic cupo-

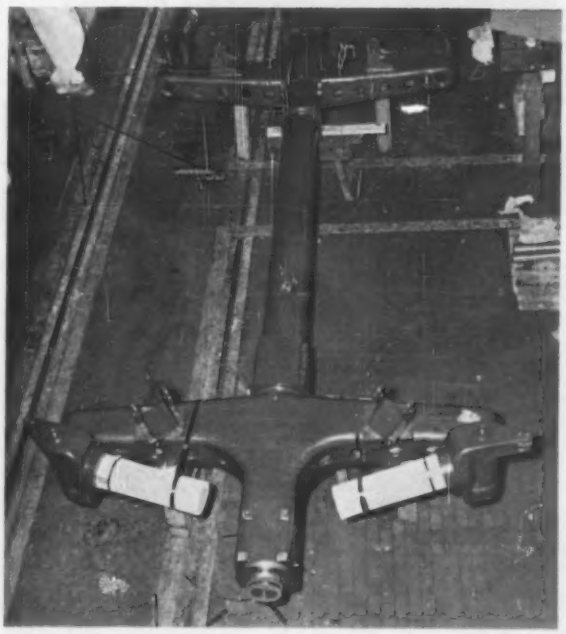


Fig. 21 — Walking beam assembly for transporting saturn missile.

Fig. 22 — 19,200 lb finish machined wire cloth roll.

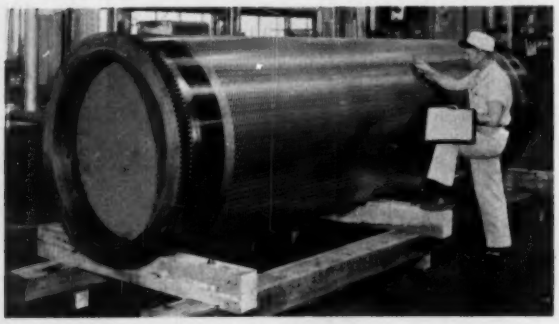


Fig. 23 — 50 in. diameter cast iron embossing roll.

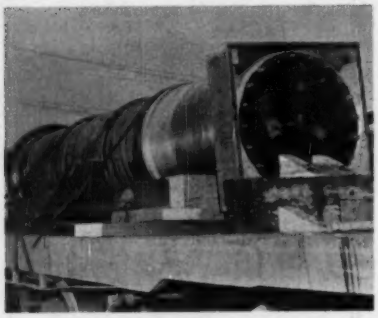


Fig. 24 — Fabricated stern tube — 33 in. O.D., 18,000 lb.

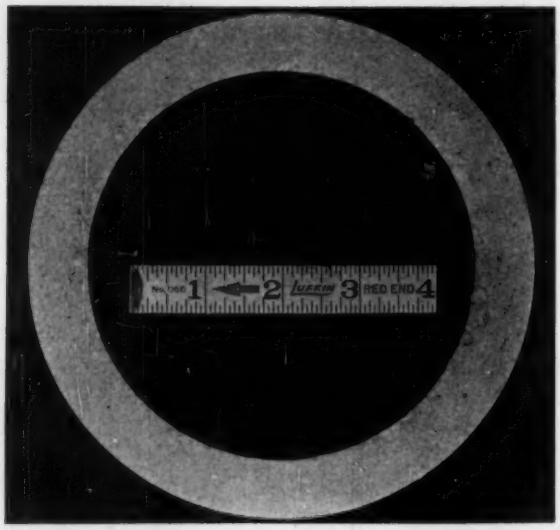


Fig. 25 — Etched ring from 6¾-in. diameter type HF stainless centrifugal.

las. The type of melting unit is chosen to best suit the type of metal to be melted.

Figure 23 shows a 45,000 psi tensile low phosphorus cast iron roll machined with an intricate diamond embossing pattern. This low phosphorus iron casting was produced with a 50.50 in. outside diameter and finished to the described surface at 50.25 in. outside diameter representing an 85 per cent yield from casting to finished product.

The stern tube shown in Fig. 24 was produced from centrifugally cast steel tubing, welded with a plate for an end flange and finish machined to 33.00 in. outside diameter x 27⅜-in. inside diameter x 16 ft long and weighed 18,000 lb.

Reformer Tube

It is of particular interest to observe successful and economic designs of reformer tube construction produced from centrifugal tubing in the heat resistant alloys where creep strengths at high temperatures are important. Figure 25 shows a full wall etched section of an A.C.I. type HF stainless tube which was spun at 120 times gravity.

This etched section and photomicrograph in Fig. 26 shows the equiaxed grain structure and the midwall soundness typical of a casting produced on ceramic molds. In recent times engineering circles have been prone to utilize new manufacturing and inspection methods in successfully designing with lower safety factors. Figure 27 shows a hydraulic cylinder fabricated from centrifugal tubing produced by the ceramic mold process which was designed to operate under 30,000 psi stress. Material from which the unit was built is 1040 steel exhibiting a yield strength of 40,000 psi as normalized and tempered.

QUALITY CONTROL AND INSPECTION

In effecting design factors such as have been indicated above, it is necessary to establish and maintain a high level of quality control. Suitable equipment, qualified personnel and standard procedures are necessary in order to meet these requirements. Following is an outline of the routine procedures and tests used in maintaining the quality demand for this production operation.

1) Accurate weighing for dimensional control. Actual weights and calipered dimensions are recorded in permanent record forms in order to verify tolerances and maintain accurate control of pouring weights.
2) Complete permanent records of each heat showing melting furnace logs, pouring temperatures, spinning speeds, pouring rates, chemical and spectrographic analyses, heat treating temperatures and physical test results.
3) 100 per cent magnetic particle inspection of ferritic materials, with operating personnel and procedures qualified according to Mil-C-7701.
4) Magnetic particle inspection at intermediate and final machining stages.
5) The application of special tests when specified or when considered advisable for the product application, such as:

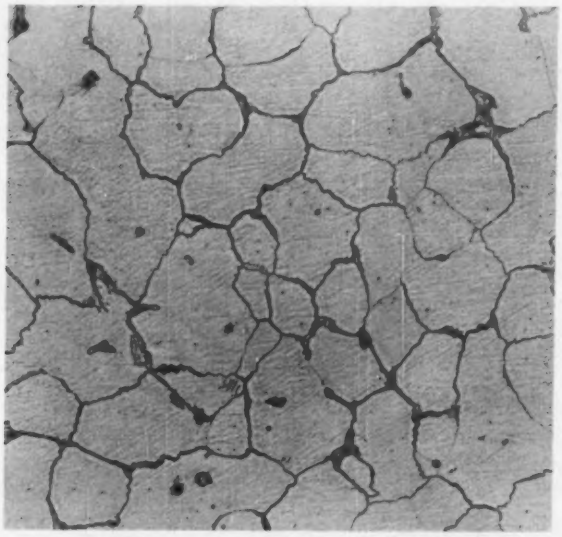


Fig. 26 — Micrograph of HF type stainless centrifugal casting. 100 ×.

a) Ultrasonic inspection in accordance with the requirements set forth in A.S.T.M. A-426—Specifications for Centrifugally Cast Ferritic Alloy Steel Pipe for High Temperature Service (Fig. 28).

b) Radiographic examination of tubing to specifications outlined in A.S.T.M. E-71—Industrial Radiograph Standards for Steel Castings.

6) Radiograph and magnetic particle inspection of weldments.

7) Welder performance and procedure qualifications such as are required by A.S.M.E., Navy, Bureau of Ships, etc. (Fig. 29).

In addition to maintaining high quality in the material produced, the rapid appraisal of the complete control system as outlined above has proven beneficial in minimizing foundry losses.

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7. E. B. Evans, L. J. Ebert and C. W. Briggs, "Fatigue Properties of Cast and Comparable Wrought Steels," *Proceedings of The American Society for Testing Materials, vol. 56*, p. 979 (1956).

Fig. 27 — Fabricated hydraulic cylinder.

Fig. 28 — Ultrasonic inspection of centrifugally cast tubing.

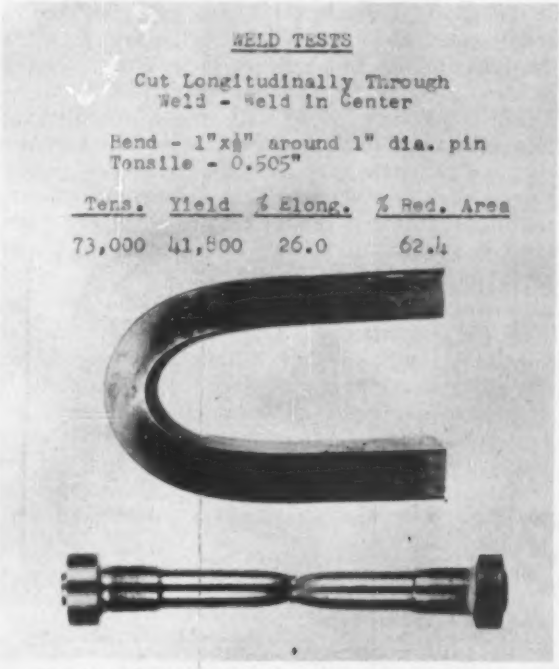
WELD TESTS
Cut Longitudinally Through
Weld - Weld in Center
Bend - 1"x¾" around 1" dia. pin
Tensile - 0.505"
Tens. Yield % Elong. % Red. Area
73,000 41,800 26.0 62.4

Fig. 29 — Typical properties of weld qualification test made on centrifugal tubing.

SOLIDIFICATION OF ALUMINUM CASTINGS

by M. C. Flemings, S. Z. Uram and H. F. Taylor

ABSTRACT

Principles underlying the solidification behavior of aluminum alloy sand castings are discussed in detail. Particular attention is paid to the influence of solidification behavior on foundry characteristics, including shrinkage and feed metal requirements, hot tearing and fluidity. Also emphasized are the interrelationships between solidification behavior, soundness, structure and mechanical properties of cast aluminum.

A section of the paper is devoted to consideration of special conditions of solidification. These special conditions include columnar dendritic growth, solidification in complete absence of dendrites, solidification into a moving liquid and movement of solid during solidification.

INTRODUCTION

Of all the engineering phases involved in manufacturing a quality casting, the phase that is often least appreciated and yet most important, is the mechanism by which the metal freezes. Mechanism of solidification determines in large part the risering requirements of foundry alloys, and is a major factor in determining characteristics such as hot tearing, fluidity, etc. An appreciation of solidification behavior is particularly important in production of aluminum castings. In many aluminum foundries a dozen or more different alloys may be poured in a single day; each alloy behaves slightly differently during solidification and so should be treated slightly differently in the shop to achieve soundness and optimum properties.

One example of the differences in solidification behavior of the different aluminum alloys is shown in Fig. 1. Sectioned castings of three alloys are shown; the alloys represent the three major classes of solidification behavior encountered in aluminum sand castings. In the pure aluminum casting (Fig. 1a) all solidification shrinkage appears as a deep "pipe" in the riser. In the 195 alloy* casting (Fig. 1b) there is almost no pipe, and solidification shrinkage reports primarily as

1) A drop in the overall riser height during the initial stages of solidification.
2) microshrinkage in the riser and usually to a lesser extent in the casting.

The casting poured of A132 alloy (Fig. 1c) shows shrinkage characteristics intermediate between those of pure aluminum and of 195 alloy; some gross shrinkage is present. Most commercial aluminum alloys show shrinkage behaviors generally similar to those of Figs. 1b or 1c.

ALUMINUM FREEZING METHOD

The pure aluminum casting freezes with deep piping because the mode of solidification is such that it freezes from the wall of the casting inwards, with a smooth front between the liquid and advancing solid. As solidification progresses and shrinkage occurs a pipe results (Fig. 2). In 195 alloy the situation is quite different (Fig. 3). In this case, solidification begins near the mold wall but progresses quickly to the center of the casting; fine grains form near the center of the casting early in the solidification process. Freezing then continues with solid metal forming in the center as well as near the walls of the casting.

It is not at all uncommon for the center of a 195 alloy casting to be over 85 per cent solid before a fully solid skin has formed on the surface. This type of solidification, shown in Fig. 3, is termed "mushy" or "pasty." In the early stages of solidification, shrinkage is compensated by settling of liquid plus solid metal in the riser; a little later, when solid grains have formed a coherent network throughout casting and riser, liquid metal drains down through the channels between the grains to feed shrinkage; still later, when the interdendritic liquid channels become too narrow to allow further passage of liquid metal, solidification shrinkage results in microporosity.

Alloy A132, an alloy of approximately eutectic composition, solidifies in a fashion somewhat similar to 195 alloy; fine grains form and grow throughout the casting during much of the solidification process. However, this alloy differs from 195 in that gross shrinkage or "pipe" is usually found in risers (Fig. 1c). Our understanding of the solidification behavior of aluminum alloys of eutectic composition is limited,[1] but it is clear that the narrow solidification

*The nominal compositions of alloys referred to in this paper are listed in the Appendix.

M. C. FLEMINGS is Asst. Prof., S. Z. URAM is Rsch. Assoc. and H. F. TAYLOR is Prof., Dept. of Met., Massachusetts Institute of Technology, Cambridge.

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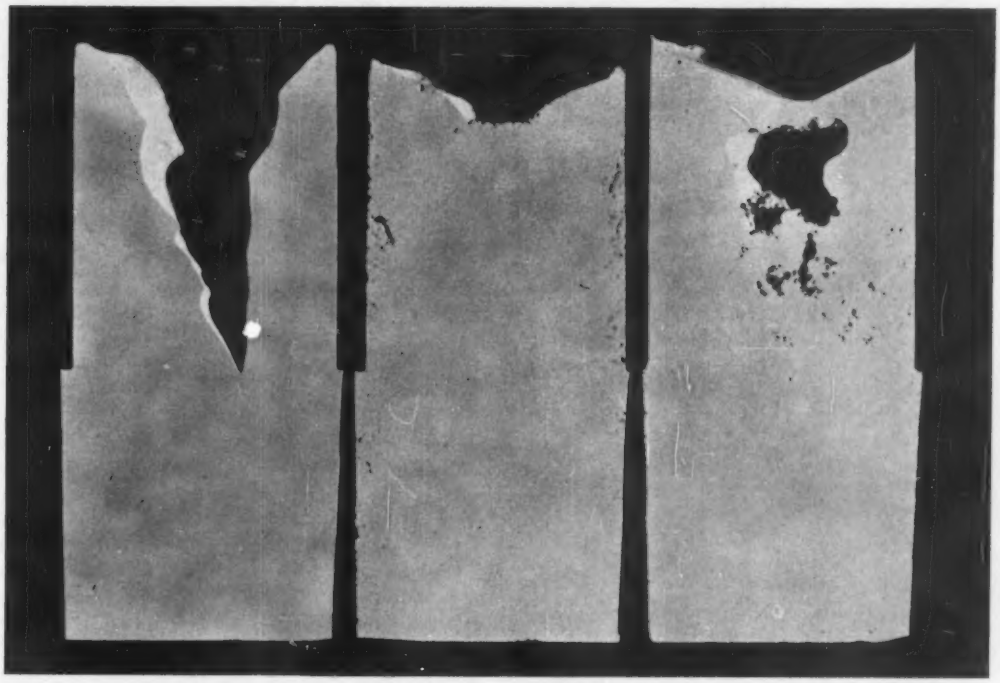


Fig. 1 — Vertical sections from top risered 5 in. cubes. *Left* — pure aluminum (99.9 per cent Al); *center* — 195 alloy (Al-4.5 per cent Cu); *right* — A132 alloy (Al-1.0 per cent Cu, 12.0 per cent Si, 1.0 per cent Mg, 2.5 per cent Ni).

range of these alloys makes them more prone to macroshrinkage than alloys which freeze over a wide temperature interval.

It is the purpose of this paper to describe the principles underlying solidification behavior of commercial aluminum casting alloys, and to show how solidification variables influence the structure and properties of cast aluminum. Most aluminum alloys of commercial importance solidify in fashions similar to 195 alloy or A132 alloy described above. In this paper detailed consideration will be given to the mechanism of solidification of high purity 195 alloy (aluminum–4.5 per cent copper alloy) because

1) It is a relatively simple binary alloy that has been extensively studied in the laboratory.
2) It is of some commercial importance.
3) principles that apply to solidification of this alloy apply also to solidification of more complex alloys.

A final section of the paper deals more generally with solidification behavior of commercial alloys.

PRINCIPLES OF SOLIDIFICATION OF ALUMINUM CASTINGS

NonEquilibrium Solidification and Microsegregation

The liquidus temperature for aluminum–4.5 per cent copper alloy is 1192 F, and the equilibrium solidus is 1059 F, Fig. 4. If solidification of such an alloy were to take place slowly enough to permit perfect diffusion in the solid state, solidification would be complete at 1059 F and the structure at that temperature would consist of a single phase solid solution

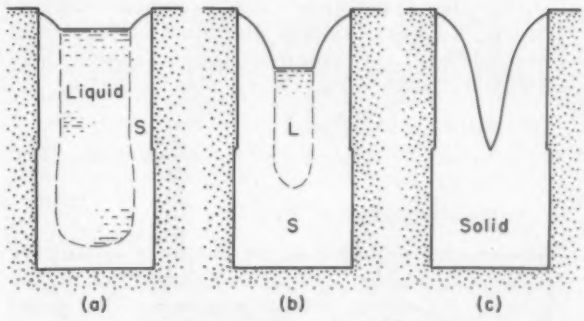


Fig. 2 — Schematic diagram of solidification of a top risered cube of pure aluminum. (a) near beginning of solidification; (b) near end of solidification; (c) end of solidification.

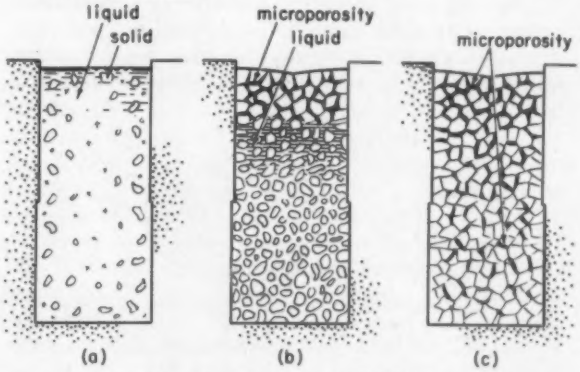


Fig. 3 — Schematic diagram of solidification of a top risered cube of 195 alloy (Al-4.5 per cent Cu). (a) near beginning of solidification; (b) near end of solidification; (c) end of solidification. Size of microporosity is exaggerated for clarity.

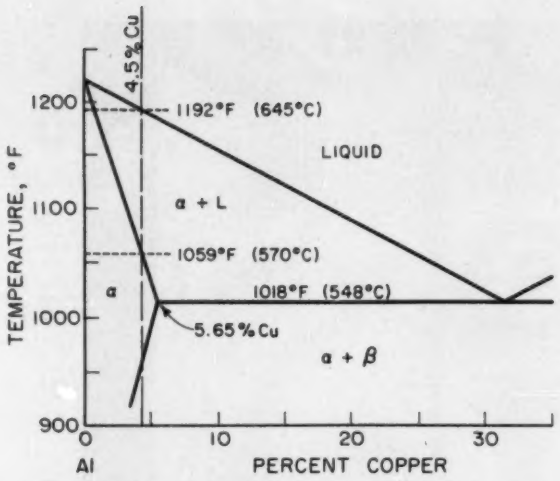


Fig. 4 — Phase diagram for the aluminum rich end of the aluminum-copper system.

of aluminum-copper. In practice, however, solidification is not slow enough to permit this degree of diffusion in the solid state; coring always occurs, and the extent of the coring is such that the alloy is never completely solid until the eutectic temperature (1018 F) is reached. The final microstructure always consists of some eutectic $CuAl_2$ as illustrated in Fig. 5.

In practice, the assumptions of "complete nonequilibrium" solidification appear to describe fairly well the solidification of aluminum-copper alloys. These assumptions are,

1) No diffusion in the solid state.
2) Complete diffusion in the liquid state on a micro-scale.
3) No macro-segregation.

Based on these assumptions, the amount of liquid present at any point in a solidifying casting can be expressed as a function of the temperature at that point, and the amount of eutectic present in the final casting can be readily determined. The mathematics underlying these calculations have been outlined by several investigators, including Scheil.[2] For alloy systems where the liquidus and solidus are essentially straight lines, the general expression for the liquid fraction can be written as a function of the liquid composition:

$$f_L = \left(\frac{C_0}{C_L}\right)^{\frac{1}{1-K}} \qquad (1)$$

where:

f_L = fraction liquid.

C_0 = initial solute concentration (per cent).

C_L = solute concentration in liquid when f_L fraction liquid remains (per cent).

K = partition ratio, $\left(K = \frac{C_s}{C_L}\right)$, where C_s = solute concentration in solid when f_L fraction liquid remains.

or it can be written as a function of the temperature at the point in question:

$$f_L = \left(\frac{M_L\ C_0}{T_m - T}\right)^{\frac{1}{1-K}} \qquad (2)$$

where:

M_L = slope of liquidus (F/%, C/%).

T_m = melting point of pure solvent (F, C).

T = temperature when f_L fraction liquid remains (F, C).

The solid line of Fig. 6 is a plot of equation (2) for a solidifying Al-4.5 per cent Cu alloy. The plot shows that at the equilibrium solidification temperature (1059 F), 12 per cent liquid remains if a casting solidifies according to the nonequilibrium assumptions described. At the eutectic temperature, 9 per cent liquid remains, and this last liquid solidifies at a single temperature to form the eutectic consisting of $CuAl_2$ and secondary.

The dashed line of Fig. 6 (from Stonebrook) was calculated from a carefully obtained cooling curve of 195 alloy.[3] Both curves of Fig. 6 show that much less solid is present at any temperature during solidification than would be the case if severe coring did not take place. The two curves shown are of similar shape, and major differences between

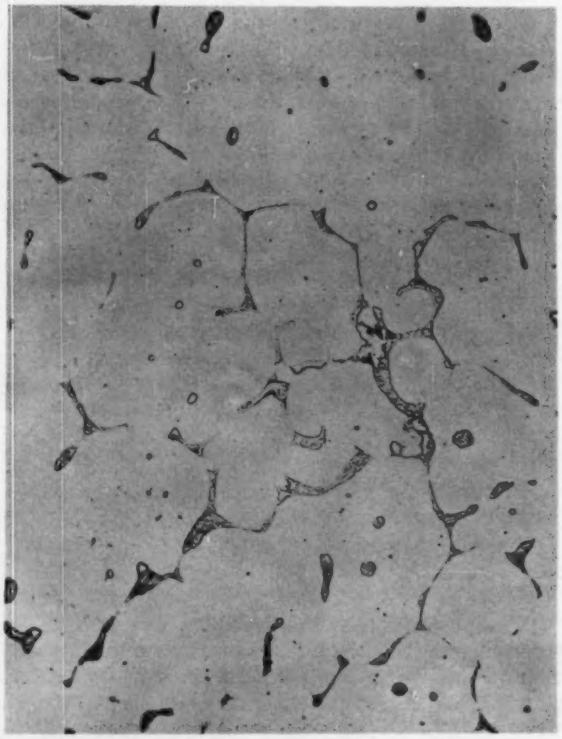


Fig. 5 — Typical microstructure of a sand cast aluminum-copper alloy (as-cast).[17] 150 ×.

the two can perhaps be explained as being due to the substantial impurities present in Stonebrook's alloy (0.78 per cent silicon, 0.59 per cent iron).

Aluminum Alloy Sand Castings
Mushy Nature of Solidification

In the solidification of aluminum alloy sand castings the main barrier to heat flow is in the sand[4] and, as a consequence, only relatively shallow temperature gradients are ever present in the metal. In all but thin castings these gradients do not usually exceed 10-20 F/in.[5,6] For example, Fig. 7 illustrates the actual temperature distribution in a solidifying plate casting (¾ x 5 x 8 in.) fed with an end riser. Thermal measurements were taken along the centerline of the long axis of the plate (Fig. 8 illustrates the design of plate used in this and subsequent studies). In the early stages of solidification, thermal gradients along the centerline were less than 5 F/in., while even in the later stages the gradients did not exceed 20 F/in.

The shallow temperature gradients obtained in ordinary sand castings of Al-4.5 per cent Cu alloy are so small, with respect to the solidification range of the alloy, that solid and liquid coexist in intimate contact throughout the casting during most of the solidification process. In castings made of metal properly grain refined, nucleation occurs more or less uniformly throughout the casting, and these nuclei then continue to grow, with growth occurring only slightly more rapidly at the end farthest away from the riser than at the end near the riser.

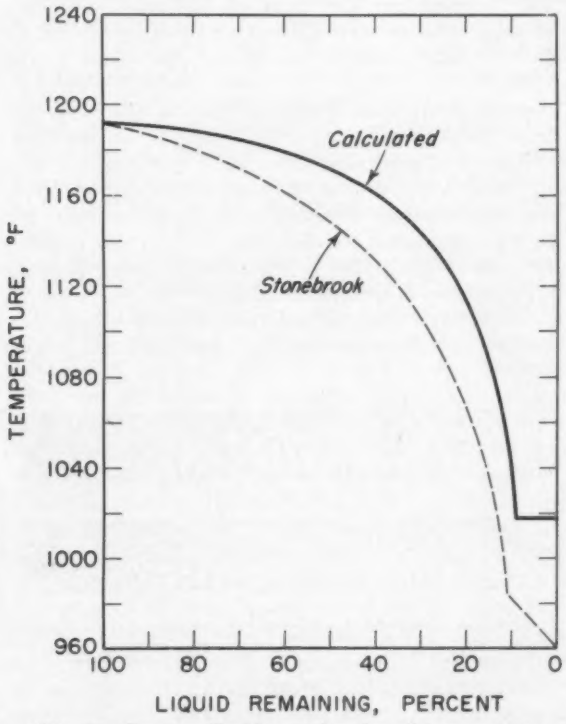


Fig. 6 — Per cent liquid as a function of temperature for a solidifying aluminum-4.5 per cent copper alloy. Solid line calculated from equation (2); dashed line from Stonebrook.[3]

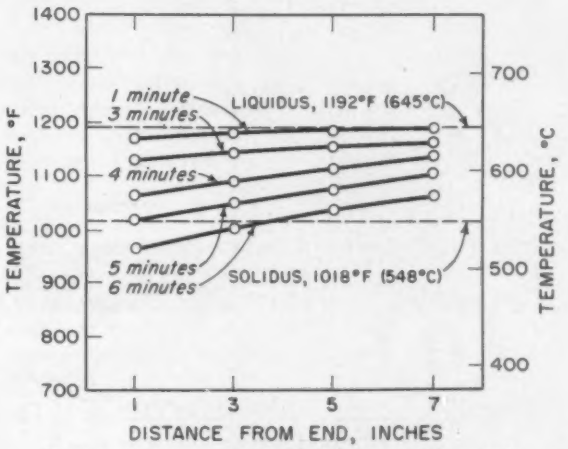


Fig. 7 — Temperature distribution along the centerline of a sand cast test plate at various times during solidification (no chill).[6] 195 alloy, ¾-in. plate (Fig. 8).

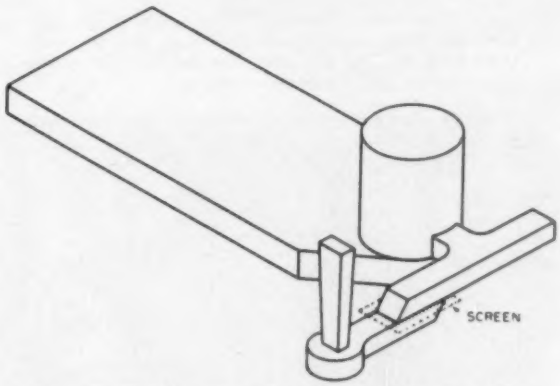


Fig. 8 — Sketch of test plate pattern. Plates studied varied in thickness from ½-in. to 1½-in.; widths were 5-6 in.

For example in the ¾-in. thick plate casting of Fig. 7, solidification is complete at the end farthest from the riser after about 5 min; at this time the centerline of the plate at the edge of the riser (6 in. from the plate end) is at a temperature of about 1075 F and, therefore, is only about 14 per cent liquid.

Thermal gradients across the thickness of the solidifying plate are also quite shallow (6 F/in. maximum during solidification) and solidification of the alloy can be visualized as the more or less uniform cooling of a pasty or "mushy" mass of liquid and solid. Figure 9 shows this type of solidification schematically. The figure is based on the thermal data of Fig. 7, and on equation (2).

During solidification of aluminum sand castings, it is probable that solidification shrinkage is fed by two quite different mechanisms.[7] In the early stages of freezing when only a small amount of solid is present, contraction is fed by bulk movement of liquid and solid. Later, when sufficient solid is present that it is no longer free to move, solidification shrinkage must be fed by liquid flowing from the feed source through narrow, tortuous, interdendritic

channels. When resistance to fluid flow becomes too great microporosity results.

Mathematical analysis based on heat flow and fluid flow considerations has shown that when interdendritic channels become sufficiently narrow, resistance to fluid flow can be appreciable and can cause microporosity to form in all but small castings.[8]

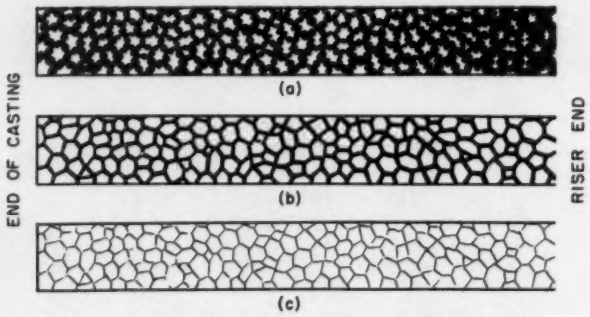


Fig. 9 — Schematic diagram of the solidification of a sand cast plate, unchilled. Plate is 6 in. long by ¾-in. thick (Fig. 8). (a) one min after casting; (b) 4 min after casting; (c) 7 min after casting.

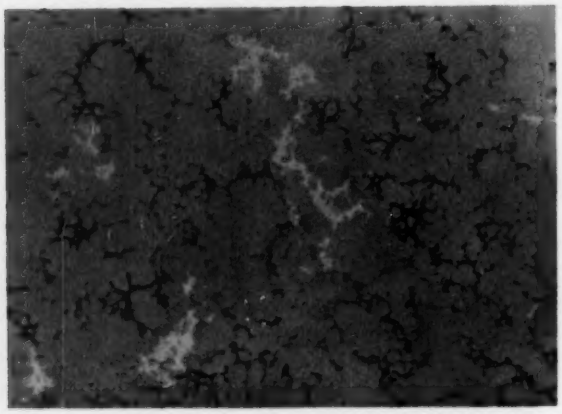


Fig. 10 — Microradiograph of a section cut from a sand casting of 195 alloy. Solution treated at 960 F, quenched aged. 16 ×.

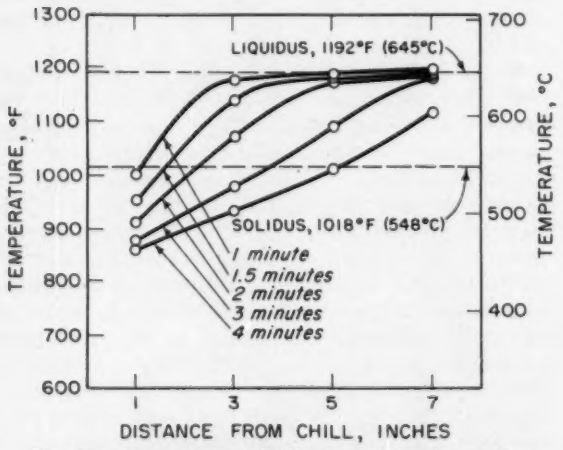


Fig. 11 — Temperature distribution along the centerline of an end chilled sand cast plate at various times during solidification.[6] 195 alloy, ¾-in. plate (Fig. 8).

The soundness of alloys which freeze in a mushy manner is dependent on the ease with which flow takes place through interdendritic channels; soundness will be increased by factors which shorten the path the liquid must flow, or otherwise facilitate its flow.

Microporosity in aluminum-copper alloys is accentuated by the presence of dissolved gas (hydrogen). This gas is much more soluble in liquid than in solid aluminum, and even small amounts dissolved in the liquid metal tend to precipitate and form micropores during solidification. For example, calculations indicate that only 0.2cc of hydrogen (at standard temperature and pressure) dissolved in 100 grams of molten aluminum will precipitate during solidification to form over 1½ per cent voids in the cast structure.[9]

Figure 10 is a microradiograph from a casting adequately risered and made from well degassed metal. It illustrates the type of microporosity which occurs in typical sand cast aluminum-copper alloys even though made by careful melting and risering practices.

Chills Effect on Mode of Solidification

Chilling of aluminum alloy sand castings results in a remarkable alteration of their mode of solidification and final structure. Metal chills absorb heat at a much more rapid rate than do sand molds, and because of this they affect the solidification of aluminum alloy sand castings in two important ways, (1) they increase solidification rate, and (2) they steepen thermal gradients in the solidifying castings. These effects may be seen by comparing the temperature distributions in two solidifying ¾-in. plates, one cast entirely in sand and the other cast in sand but chilled at its end (Figs. 7 and 11).

At a point 1 in. from the end of the unchilled plate, solidification was complete after 5-6 min, and thermal gradients near the end of solidification were 15 F/in. At a similar point in the chilled plate, solidification was complete after only one min, and thermal gradients at this time were approximately 100 F/in. Figure 12 is a schematic diagram showing solidification of this chilled plate.

Steep thermal gradients in solidifying castings are usually desirable because they minimize the length

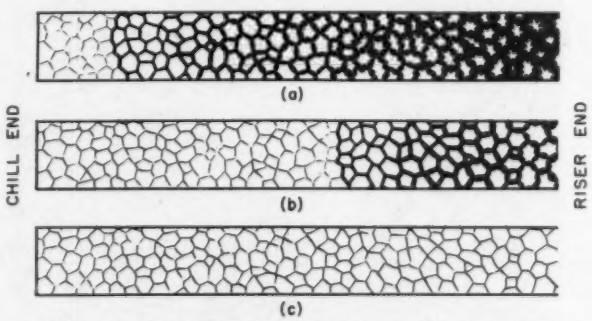


Fig. 12 — Schematic diagram of the solidification of a sand cast plate, end chilled. Plate is 6 in. long by ¾-in. thick (Fig. 8). (a) one min after casting; (b) 3 min after casting; (c) 5 min after casting.

Fig. 13 — Microradiographs of sections cut from an end chilled ¾-in. sand cast plate, aluminum-4.5 per cent copper alloy. 16 ×.[17] Light areas are microporosity, dark areas are undissolved aluminum-copper intermetallic. Specimens solution treated at 960 F and aged. *Left* — 0.4 in. from chill; *right* — 5.4 in. from chill.

in the casting over which liquid and solid coexist; they minimize the "mushy zone." By so doing, the gradients reduce the length of the tortuous paths over which liquid must travel to feed solidification shrinkage. Thus chills, by steepening thermal gradients, tend to minimize microporosity. The second effect of chills, that of increasing solidification rate, also has certain beneficial effects on the cast structure.

Increased rates of solidification of nonferrous alloys result in dendrites with a smaller arm spacing,[10] and with a finer, more even distribution of microconstituents. The improved properties to be obtained from the more homogeneous cast structure are described in detail in a later section. Rapid solidification rates also, of course, tend to result in a finer cast grain size, but in aluminum alloys this reduction (for properly grain refined alloys) is not large.[11,12]

In the case of 195 alloy, the structural improvements to be obtained by chilling are illustrated in Fig. 13. Near a chill, the mast metal is free of microporosity, and the Cu Al_2 formed during solidification is of such a finely divided form that ordinary heat treatments readily dissolve it (Fig. 13a). At locations in the casting which are some distance away from the chill, microporosity is more readily formed, and the $CuAl_2$ is in a coarse form that is not readily dissolved in heat treatment (Fig. 13b).

As described above, chills substantially reduce the length of the mushy zone of solidifying 195 alloy castings; chills cannot, however, entirely eliminate the zone. This is in part due to lateral heat flow through the sand mold and in part because even with no heat losses, the mode of solidification of the alloy is such that a region of solid plus liquid must exist over at least a limited zone (mushy zone) of the casting during solidification. Heat flow calculations show that even with optimum chilling (water chill and no contact resistance) the length of the mushy zone must usually be almost as long as the length of metal solidified.[13]

Experimental studies have confirmed the preceding conclusion. The test pattern used in the studies was a ½-in. thick plate similar to that shown in Fig. 8. The pattern was end cooled with a water chill, and molded in three different media to obtain differing degrees of lateral heat flow. These media were 1) plaster mold heated to 900 F just before pouring, 2) plaster mold heated to 450 F just before pouring, and 3) core sand mold at room temperature.[11]

A schematic representation of the structure and temperature distribution in the test plate at a particular time during solidification is shown in Fig. 14. When a length (X_s) is completely solid, liquid plus solid exist together over the length of the mushy zone (ΔX_{100}). For analytical purposes, an arbitrary mushy zone consisting of solid plus liquid, but not over 30 per cent liquid, was chosen (Shown as ΔX_{30}). It was felt that where more than about 30 per cent liquid existed in the liquid-solid region, little resistance to feeding would be encountered. The relationship of Fig. 6 was used to determine the temperature limits of 0-30 per cent liquid; these are 1018 F to 1143 F.

The length of metal solidified (X_s) versus the square root of time for each of the plates is shown in Fig. 15. The plot is a straight line for the plaster mold heated to 900 F, indicating essentially unidirectional heat flow.[13] The plot for the cooler plaster mold shows some curvature, and the plot for the core sand mold shows markedly greater curvature, indicating increasing lateral heating losses to the molding media.

When heat flow is unidirectional, the length of the specified mushy zone is relatively small compared to unchilled sand castings, but is still significant (Fig. 16). It is directly proportional to the length of to-

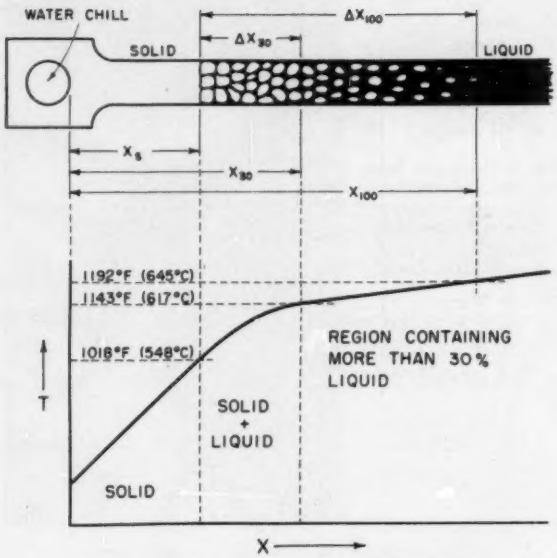


Fig. 14 — Schematic representation of solidification of an aluminum-4.5 per cent copper alloy end chilled plate.[11] *Top* — solidification structure when a length X_s is completely solid; *bottom* — temperature distribution when a length X_s is completely solid.

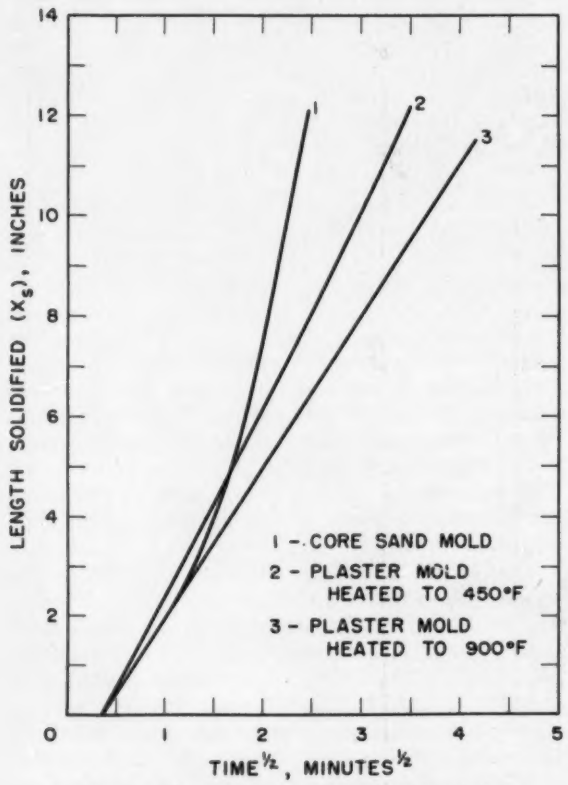

LENGTH SOLIDIFIED (X_s), INCHES
TIME$^{1/2}$, MINUTES$^{1/2}$
1 - CORE SAND MOLD
2 - PLASTER MOLD HEATED TO 450°F
3 - PLASTER MOLD HEATED TO 900°F

Fig. 15 — Length of completely solidified metal vs. time in end chilled plates.[11] 195 alloy, water chilled ½-in. plates (Fig. 8).

tally solid metal as would be predicted from heat flow relationships.[13] When lateral heat losses increase, the length of the mushy zone also increases. It is to be expected that the longer mushy zones will result in greater feeding difficulties, and hence more microporosity and a casting of somewhat lower mechanical properties.

Grain Refinement

Most hypoeutectic aluminum alloys (including aluminum-4.5 per cent copper alloy) are grain refined by addition of a suitable nucleating agent. Titanium and/or boron are employed and these agents are so effective in their action that undercooling at the liquidus temperature is virtually eliminated.[14] Grain refinement is of practical importance primarily because of the improved mechanical properties that results.[12,14] These improved properties are obtained not because of the reduced grain size, per se, but because of the finer distribution of microporosity and intermetallics that is obtained in fine grained material.[14]

The effectiveness of titanium as a grain refiner is thought to stem from formation of titanium carbide particles that act as nucleating sites for growth of solid aluminum. Similarly, boron is thought to form aluminum boride particles.[15] Whichever element is used for grain refining, excessive superheat and/or repeated remelting can destroy the effectiveness of the particles; when this happens coarse grains result. Figure 17 shows the relation between titanium content, melting temperature and grain size for aluminum-4.5 per cent copper alloy.

SOLIDIFICATION STRUCTURE EFFECT ON MECHANICAL PROPERTIES

Unchilled castings of aluminum-copper alloys exhibit the generally recognized effect of section size on mechanical properties; i.e., thinner sections exhibit somewhat higher properties than thicker ones (Fig. 18). Detailed examinations have indicated that this is primarily due to a finer distribution of microporosity and intermetallics in the thinner castings, there being relatively little difference in the grain size (when proper grain refinement is employed).

The effect of section size on mechanical properties

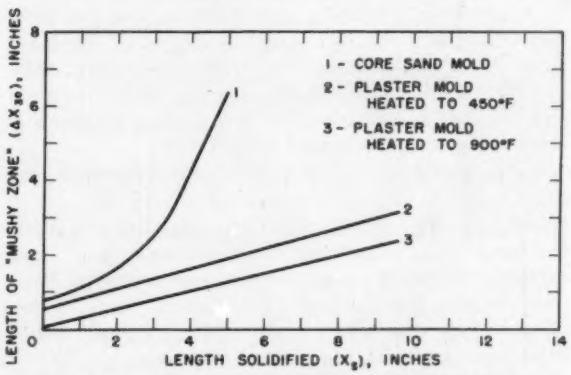

LENGTH OF "MUSHY ZONE" (ΔX_{30}), INCHES
LENGTH SOLIDIFIED (X_s), INCHES
1 - CORE SAND MOLD
2 - PLASTER MOLD HEATED TO 450°F
3 - PLASTER MOLD HEATED TO 900°F

Fig. 16 — Length of mushy zone at various stages of solidification of end chilled plates.[11] 195 alloy, water chilled ½-in. plates (Fig. 8).

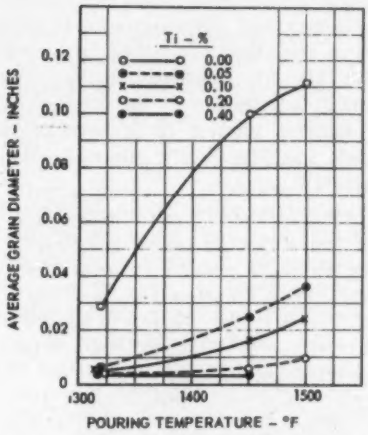


Fig. 17 — Effect of pouring temperature and per cent titanium on the grain size of cast aluminum-4.5 per cent copper alloy.[12]

is quite small when compared to the effect to be obtained by chilling. For example, when a chill is placed at the extremity of a 195 alloy plate section (as illustrated in Fig. 8), mechanical properties of the section near the chill are raised from approximately 37,000; 27,000; 3* to 57,000; 30,000; 18. More importantly, the chills not only improve the properties of immediately adjacent areas, but also have a beneficial effect at distances well removed from the chill (Fig. 19).[16]

In a previous section of this paper, chills were shown to alter the casting structure by 1) reducing microporosity, and 2) refining the size and distribution of intermetallic compounds. Related investigations have shown that the improved mechanical properties effected by chilling result primarily from the above two structural changes.[6,9,16,17,18] Reduction of microporosity eliminates damaging areas of stress concentration. Refinement of $CuAl_2$ permits more adequate solutionizing of the compound at ordinary solution treating temperature, and refinement of other intermetallic compounds makes these compounds less damaging to mechanical properties. The effects of these structural variables are discussed quantitatively and in more detail in subsequent sections.

In general, chills appear somewhat more effective in improving the mechanical properties of castings with thicker sections than with thin sections. This has been ascribed to the better directionality of solidification (and feeding) obtainable in thicker sections wherein lateral heat losses are a smaller portion of the total heat extracted (Fig. 16).[11]

Figures 13a and 13b illustrated the effect of chillin in refining the $CuAl_2$ segregate so that it can be more completely dissolved during heat treatment. At distances removed from a chill the segregate is present in such coarse distribution that it is not completely dissolved by ordinary heat treatments, and it has been reasoned that the presence of these brittle grain boundary constituents might impair mechanical properties of the alloy. To investigate quantitatively the effect of the segregate on mechanical prop-

*The shorthand 37,000; 27,000; 3 is used to denote 37,000 psi ultimate tensile strength, 27,000 psi yield strength, 3 per cent elongation.

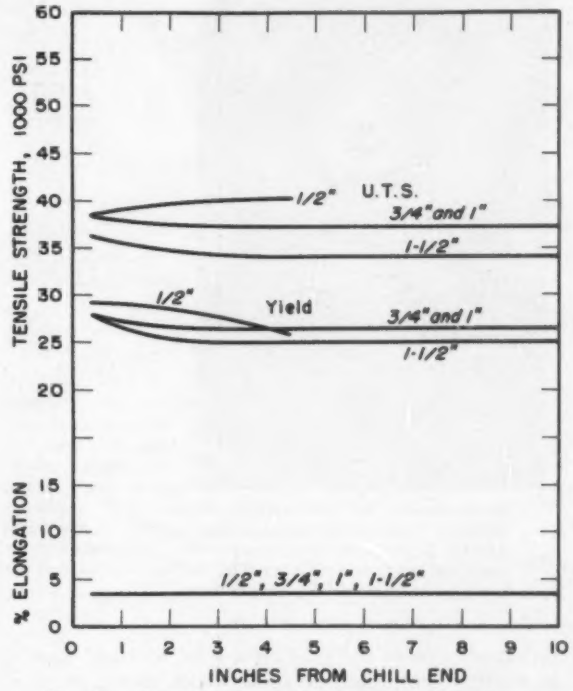


Fig. 18 — Summary of tensile properties of sand cast test plates, no chill.[16] 195 alloy, solution treated 960 F, quenched and aged (Fig. 8).

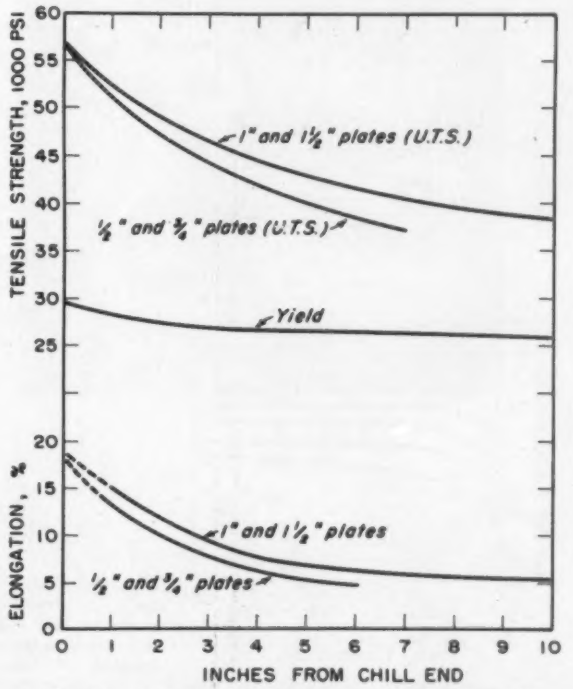


Fig. 19 — Summary of tensile properties of end chilled sand cast test plates.[16] 195 alloy, solution treated 960 F, quenched and aged.

Fig. 20 — Microradiograph of section cut from an end chilled ¾-in. sand cast plate, aluminum-4.5 per cent copper alloy. 16 ×.[17] Specimen solution treated four days; final solution temperature 1010 F. Light areas are microporosity. This specimen is identical to that shown in Fig. 13(b), except for the higher solution treating temperature.

erties, a series of chilled plates were solution treated at various temperatures above those normally used in practice (above 960 F). The effect of these solution treatments on structure and mechanical properties were then determined.[17]

In the case of 195 alloy, solutionizing temperatures in excess of 1010 F were found to completely dissolve the $CuAl_2$, even at distances well removed from a chill (Fig. 20). A substantial improvement in mechanical properties of the alloy was found to accompany this treatment (Fig. 21). Solution treating temperatures above 960 F had relatively little effect on the properties of sections near a chill, because in these areas the $CuAl_2$ was sufficiently fine to be adequately dissolved at 960 F.

In commercial aluminum-copper alloys, impurities are always present which may form intermetallic compounds fully as damaging to the mechanical properties of the alloy as is coarse $CuAl_2$. One of these intermetallics is iron which forms the grain boundary intermetallic compound Cu_2FeAl_7 in high purity aluminum-copper alloys.[19] Chilling tends to refine the size and distribution of the intermetallic, but intensive solution treatments will not dissolve it. As illustrated in Fig. 22, these particles are quite damaging to the properties of cast 195 alloy. Their effect is more pronounced in the more slowly cooled locations of a casting (where their structure is coarser).[17] High purity, especially with regard to iron content is an essential step in the production of aluminum alloy castings of high strength and high ductility.

SPECIAL SOLIDIFICATION SITUATIONS

Columnar Grain Formation

Columnar grain structures are seldom, if ever, encountered in properly grain refined commercial aluminum alloys. However, in the absence of grain refining agents, and with sufficiently high pouring tem-

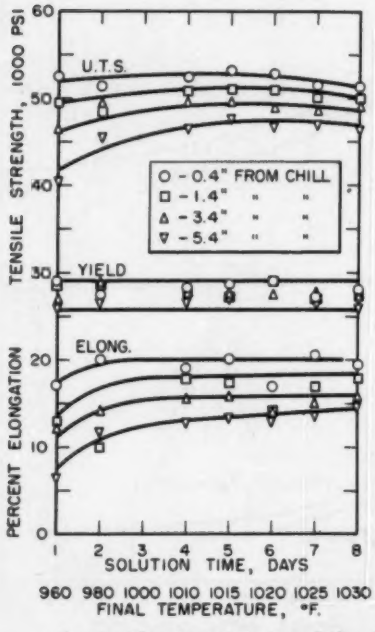


Fig. 21 — Summary of tensile properties of end chilled plates as a function of solution treating temperature and time.[17] ¾-in. end chilled plates, 195 alloy (Fig. 8). Progressive solution treatments were employed, i.e., one day at 960 F, plus one day at 980 F, plus one day at 1000 F, etc., until the desired final solution temperature was reached. Following solution treatment, specimens were quenched and aged.

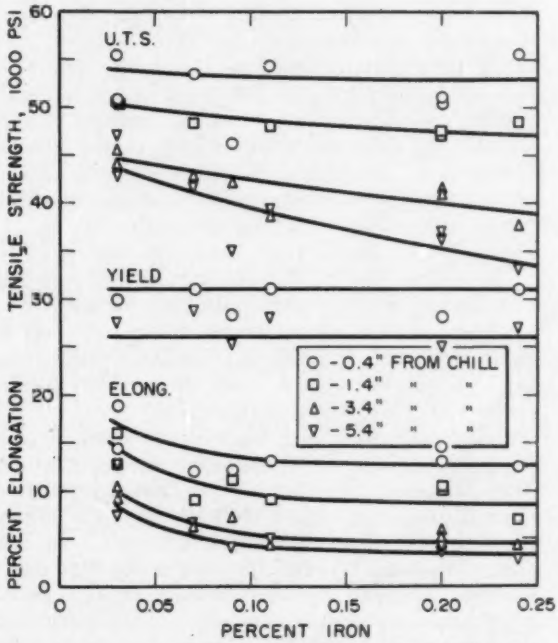


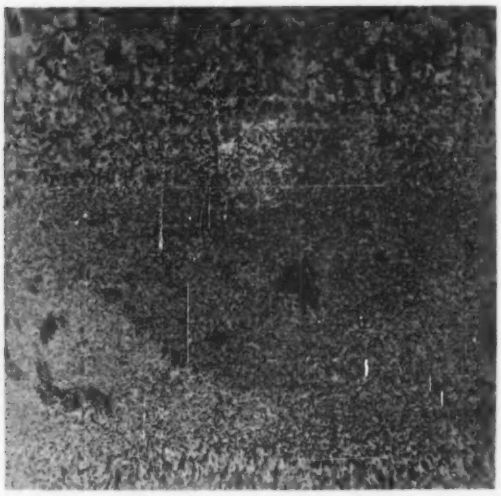
Fig. 22 — Summary of tensile properties of end chilled test plates as a function of iron content.[17] 195 alloy, ¾-in. plates, solution treated at 960 F, quenched and aged. Note — the mechanical properties at locations near a chill are less affected by the impurity than are the properties at distances removed from the chill.

perature, it is possible to obtain columnar grains in alloys such as aluminum–4.5 per cent copper. Figure 23 illustrates structures of three castings which were water cooled at the bottom and fully insulated on the sides and top during solidification.[18] Castings poured at temperatures below 1210 F exhibited a fine grain structure; with pouring temperatures near 1275 F columnar grains were obtained; and with higher pouring temperatures, large twin grains resulted (Fig. 23).

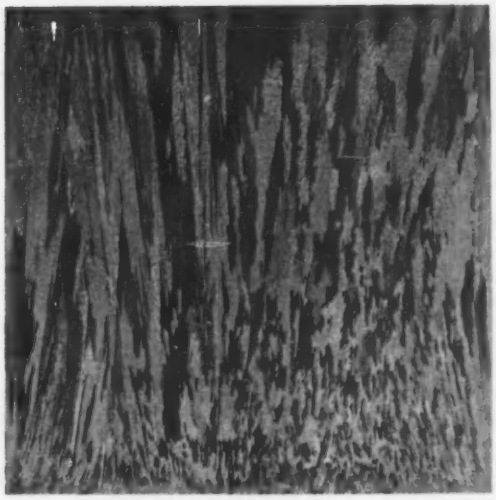
It is of interest that microconstituents and microporosity tend to line up in a fibrous array in the columnar and twinned grain material. As a result, these structures do not exhibit isotropic properties; tensile strengths in the direction parallel to the columnar crystals may be as much as 50 per cent greater than in the direction perpendicular to the crystals; elongation in the direction parallel to the crystals may be 100 per cent greater.

Prevention of Dendrite Formation

Theoretical and experimental investigations have shown that regardless of rate of cooling, normal sand or chilled castings of aluminum-copper alloys (such as aluminum-4.5 per cent copper) freeze with a liq-



Pouring temperature 1210 F (655 C).



Pouring temperature 1275 F (690 C).

Pouring temperature 1320 F (715 C).

Fig. 23 — Structures obtained in cast aluminum-4.5 per cent copper alloy by varying pouring temperatures.[18] Test castings were 3⅜-in. diameter by 6 in. high, bottom chilled and insulated on sides and top by a heated sand mold. Structures shown are etched sections cut vertically through the center of the specimens.

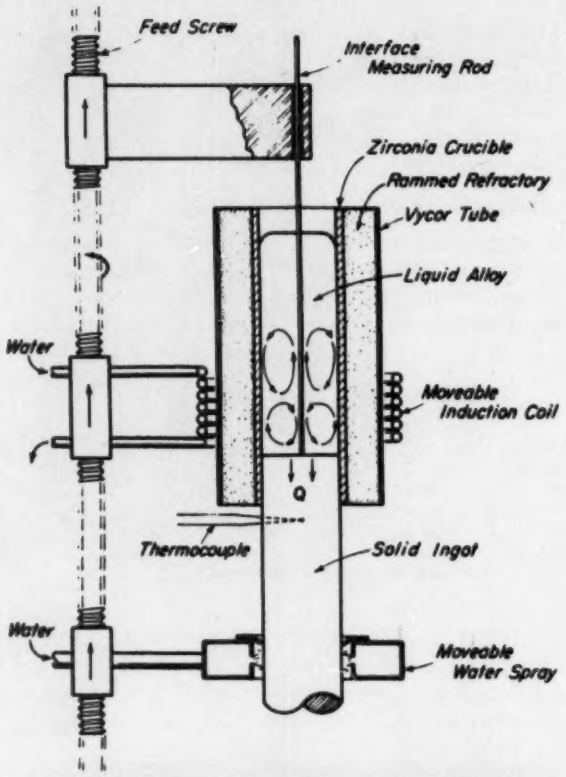


Fig. 24 — Schematic diagram of apparatus to solidify aluminum alloys under conditions of (a) steep temperature gradients, (b) slow solidification rates and (c) rapid stirring in the liquid metal.[21,22] Temperature gradient and solidification rate are essentially independent variables at low solidification rates.

uid-solid mushy zone, and that the grains in this zone grow either as columnar or equiaxed dendrites. In both these cases, microporosity and intermetallic compounds tend to segregate between the dendrite arms and at the boundaries between the dendrites, creating zones of mechanical weakness.

If, however, thermal gradients were increased by adding heat to the molten alloy during solidification and by severely chilling the alloy, it is possible to eliminate the liquid-solid zone; i.e., to obtain essentially plane-front solidification and eliminate dendrite formation. Rapid stirring aids in obtaining plane-front solidification by promoting diffusion in the bulk liquid.

A schematic diagram of an apparatus designed to achieve such steep temperature gradients and liquid stirring is sketched in Fig. 24. A low frequency induction coil was used to obtain both heating and stirring of the liquid phase. A water spray was used as a chill. Solidification was achieved by slowly moving the coil and water spray upwards. At sufficiently steep temperature gradients and slow solidification rates, microstructures free from any apparent dendritic traces or microsegregation were obtained.

Note that in the apparatus shown thermal gradients and solidification rate are independent variables (at sufficiently low rates of solidification). Rate of solidification is determined by the rate of upward movement of the induction coil-water spray assembly. Thermal gradients (in the solid) are determined by the distance between the water spray and the liquid-solid interface.

The conditions necessary to prevent dendrite formation and cause solidification to proceed on a flat advancing plane-front have been discussed by a number of investigators, including Wagner,[20] Tiller, et al.[21] The specific conditions affecting such freezing of aluminum alloys were studied in the investigation described here.[22] From the preceding analyses, it can be shown that in order for solidification of an alloy to proceed in this plane-front manner, a minimum temperature gradient must be present in the liquid (at the liquid-solid interface) which may be expressed by the equation:

$$G_L = -\frac{mu\,C_s(1-K)}{DK} \qquad (3)$$

where:

G_L = minimum temperature gradients in liquid at the liquid-solid interface to produce plane-front solidification (F/in., C/cm).
m = slope of liquidus (F/%).
u = rate of movement of liquid-solid interface (in./hr).
C_s = composition of freezing solid (%).
K = partition ratio = 0.172 for aluminum-copper system.
D = diffusion coefficient (hr/in.$^{-2}$) of solute atoms in liquid.

Thus, plane-front solidification (and elimination of the dendritic mode of freezing) is favored by 1) low solute concentrations, 2) an alloy whose phase diagram has a small slope and large partition ratio, 3) low solidification velocities and 4) a high diffusion coefficient of solute atoms in the liquid metal. Rapid stirring also aids the attainment of plane-front solidification by lowering C_s.[20-22]

Equation (3) indicates that for a given alloy system, the minimum temperature gradient in the liquid (G_L) which will produce "plane-front" solidification is a function of solidifying composition and solidification rate:

$$\frac{G_L}{C_s} = C'u \qquad (4)$$

where C′ = constant.

Since the gradients in the liquid at the liquid-solid interface are roughly proportional to the gradients in the solid at the interface;[22]

$$\frac{G_s}{C_s} = C''u \qquad (5)$$

where:

G_s = minimum temperature gradients in solid at the liquid-solid interface to produce plane-front solidification (F/in.).
C″ = constant.

Using the apparatus of Fig. 24, a series of aluminum-copper alloys were solidified under various temperature gradients (G_s) and at various solidification rates (u). The solidified ingots were analyzed to determine C_s. Results are plotted in Fig. 25 with

the parameters of equation (5). Two types of cast structures were found in ingots solidified in this manner. They were 1) fine grained ingots possessing an obvious dendritic structure with microsegregation and some microporosity, and 2) large columnar appearing grains which were free of all apparent dendritic traces, microsegregation and microporosity.

The fine grained structures were obtained at relatively low G_s/C_s ratios and high solidification velocities (u). A line separating the fine grain structures from those which are free of dendritic segregation can be drawn on the graph of Fig. 25; such a line conforms to the theoretical relationship of equation (5). It can be calculated from Fig. 25 that an aluminum 4.5 per cent copper alloy, solidifying under thermal gradients of 450 F/in. would have to be frozen at rates less than 0.9 in./hr to obtain a dendrite free structure.

Such slow solidification rates (especially when steep temperature gradients must be maintained) are not practical for the production of high strength aluminum-copper alloy castings, although the homogeneous cast structure obtained would certainly be advantageous, especially in ingots cast for subsequent working.

Other Special Situations

Space limitation precludes a full treatment of the effects of the many special casting conditions on solidification and solidification structure. However, brief mention of some of these is pertinent:

1) Unusual structure and segregation effects are sometimes seen in aluminum alloys when there is a high degree of stirring or motion of the liquid in contact with growing solid. Examples of such cases are noted in centrifugal casting of pipes or bearings, in fluidity spirals or when metal is run slowly over a chill in filling an ordinary sand casting. In such cases there is a pronounced tendency for columnar grains to form, and these grains are tilted with respect to the mold wall so they point upstream; i.e., they lean into the director of flow.[23] If heat or fluid flow variables are interrupted during flow, a banding type of segregation can result; this has been suggested as one cause of banding in centrifugally cast aluminum bearings.[23]

2) Flotation or settling of solid crystals during solidification can also produce unexpected effects. One example is the large grains that are sometimes seen near the cope in otherwise fine grained castings. This has been explained as being attributable to the settling of nuclei during freezing.[24] In some alloys, the fine crystallites float rather than sink, and shrinkage may be encountered at the bottom, instead of the top of castings.[25]

3) Macrosegregation is nearly always present in aluminum castings, although usually to such a slight degree as to be unimportant commercially. The macrosegregation is nearly always inverse; i.e., portions at or near the surface of a casting are found to be richer in solute than portions in the interior. This results because of the mushy nature of solidification of aluminum alloys and because the last liquid

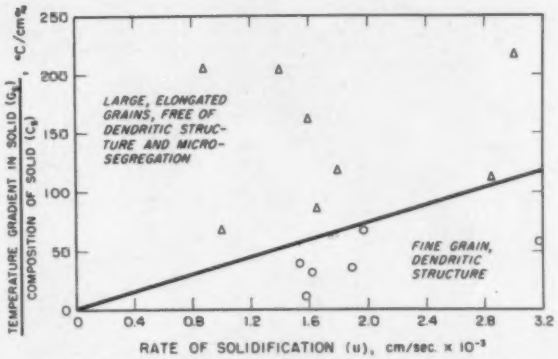


Fig. 25 — G_s/C_s vs. u for aluminum-copper alloy heats.[21,22] Graph illustrates that samples solidified at relatively high thermal gradients, or with a low solute concentration (high G_s/C_s), and a relatively slow rate (low u), tend to freeze with a homogeneous structure free of dendrites. *Triangles* — experimental heats which solidified free of dendritic structure. *Circles* — experimental heats which solidified with an equiaxed dendritic structure.

to freeze contains a high concentration of solute (for example, the last liquid to freeze in a casting of aluminum-4.5 per cent copper alloy contains 33 per cent copper).

The solute rich liquid flows between dendrites during freezing to compensate for solidification contraction; as a result, regions far from a source of feed metal may become richest in alloy. A number of authors have discussed inverse segregation in aluminum in detail, and described the various types that are encountered and the factors which influence it. These authors include Murphy,[26] Adams,[27] Youdelis[28] and others.

It is of practical interest that contraction stresses during solidification can influence segregation by the mechanism described above. The stresses act to separate freezing dendrites, so that more solute rich liquid must flow to fill the added volume. Figure 26 is an example of segregation resulting from solidification contraction. With careful heat treatment practices, segregation of this kind need not be deleterious to mechanical properties.

Solidification Variables and Foundry Characteristics

Foundry characteristics which are strongly dependent on mode of solidification include shrinkage, hot tearing, fluidity and others. Figures 1 to 3 at the beginning of this paper illustrate the marked effect of solidification variables on shrinkage. Pure aluminum, solidifying from the mold wall inwards, exhibits a deep pipe in the riser; the pure metal is also subject to centerline shrinkage unless adequate temperature gradients are maintained during freezing.

Alloy 195, which freezes over a wide temperature interval in mushy fashion shows almost no pipe, but is prone to microporosity when feeding is not complete. Alloy A132, of approximately eutectic composition, freezes over a narrow temperature interval, and solidification shrinkage again shows up primarily as a piping type cavity in the riser. As with pure

Fig. 26 — Microradiograph of critical area of hot tear test casting. Aluminum-9.96 per cent copper (not grain refined). Dark streaks are segregate; light areas are incipient tears or microporosity. Original magnification approximately 8 ×.[30]

aluminum, castings of A132 alloy are subject to centerline shrinkage unless properly fed.

In practice it is usually found that alloys which freeze over a wide temperature interval, but with only a small amount of eutectic in the microstructure, are most prone to microporosity and are most difficult to feed to complete soundness. It has been stated that best feeding characteristics are obtained in alloys containing from 40 to 80 per cent eutectic.[29] Alloys containing less than this amount of eutectic are prone to microporosity, and alloys containing greater amounts of eutectic are susceptible to centerline shrinkage.

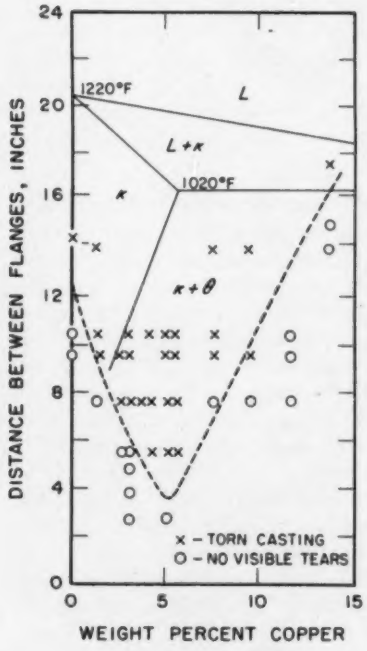


Fig. 27 — Hot tearing characteristics of aluminum-copper alloys, superimposed on portion of phase diagram.[30] "Increasing distance between flanges" indicates increasing resistance to hot tearing.

The commercial aluminum-zinc-magnesium alloys are among the most difficult to feed; these alloys freeze over a range of some 400 to 500 F, with almost no residual eutectic. Aluminum 4.5 per cent copper is less difficult to feed (the alloy freezes over a range of approximately 174 F, with 9 per cent residual eutectic). Considerably improved feeding can be obtained with alloys containing 5 or more per cent silicon; these alloys freeze over a narrower range than aluminum-copper alloys, and possess from 40 to 100 per cent eutectic (widely used aluminum-silicon alloys include 43, 355, 356, A132, etc.).

Aluminum Alloy Hot Tearing

Hot tearing characteristics of aluminum alloys are influenced by many of the same factors that influence feeding, and alloys that are subject to microporosity also tend to be prone to hot tear. Thus, in any given casting, 356 alloy is less likely to hot tear than 195 alloy, and 195 in turn is less likely to tear than one of the aluminum-zinc-magnesium alloys. Figure 27 illustrates hot tearing tendencies of a series of aluminum-copper alloys. Minimum resistance to tearing occurs at about 5 per cent copper; this resistance increases with both increasing and decreasing copper content.

In a recent study[30] is was concluded that copper in amounts of 5 per cent lowers resistance to hot tearing by forming isolated liquid pools which do not fully solidify until the eutectic temperature is reached. These liquid pools embrittle the matrix metal at temperature above the eutectic temperature. In aluminum-copper alloys containing over 5 per cent cop-

per, it was concluded sufficient eutectic is present so eutectic liquid can flow to feed incipient hot tears. In general, relatively small amounts of alloying elements decrease resistance to hot tearing of pure aluminum, but when enough of an alloy is added, resistance to tearing again increases.

Fluidity, the last foundry characteristic to be considered herein, is as strongly dependent on mode of solidification as is any of the foundry characteristics heretofore considered. Figure 28 illustrates comparative fluidities of five different foundry alloys, tested in a green sand mold fluidity spiral.[31] After several years' research it has been concluded that solidification variables are primarily responsible for the differences in fluidity among the different alloys. Such factors as surface tension, surface oxides, metal viscosity, etc., appear to play little part in affecting fluidity test results in sand molds[31,32,33] (except, perhaps, in sections appreciably thinner than those usually cast.[34]

Typical curves of fluidity versus composition in an aluminum binary system are shown in Fig. 29. Small amounts of alloying elements reduce fluidity by changing the mode of solidification from smooth, plane front to columnar dendritic. The dendrites reach out into the flowing metal and tend to stop flow more quickly than does a smooth solid wall. As solute content is further increased, fine, equiaxed grains form and may choke the flow of metal still more quickly. As the eutectic composition is approached fluidity is generally found to increase, due perhaps because not enough primary crystals form to completely choke flow.[32,33,35] This increase in fluidity near eutectic composition has not, however, been found for all systems.[36]

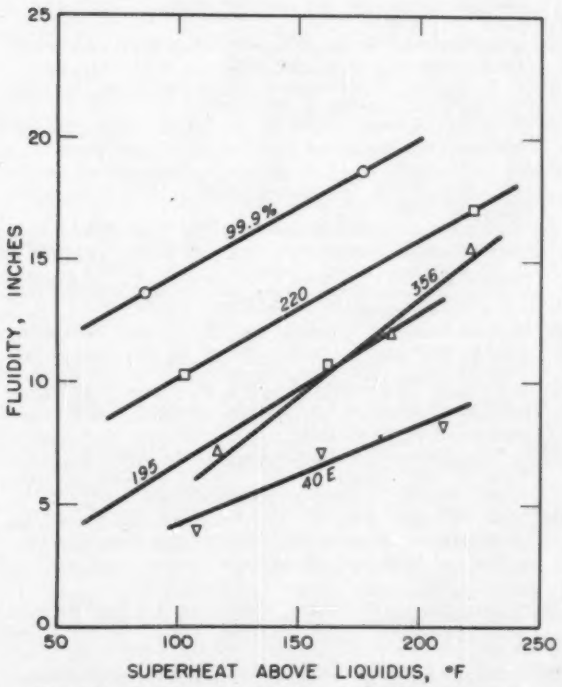


Fig. 28 — Fluidity as a function of superheat above the liquidus of some commercial casting alloys.[31]

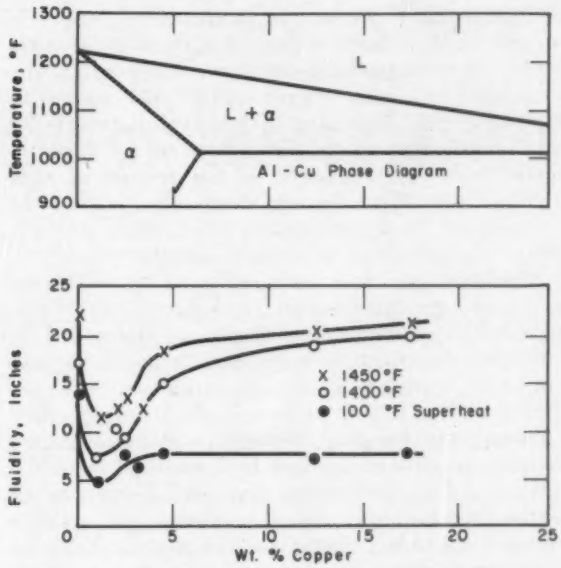


Fig. 29 — Fluidity vs. composition for the aluminum-copper system at various pouring temperatures.[31]

SUMMARY

The purpose of this paper has been to discuss the principles underlying solidification behavior of aluminum alloys. Much of the paper has dealt with solidification of aluminum-4.5 per cent copper alloy, because 1) a large amount of fundamental research has been conducted on this alloy and 2) the principles of solidification that apply to aluminum-copper alloys apply as well to the many other more widely used commercial casting alloys. Also, 195 alloy is a relatively simple binary system of some commercial importance.

Most aluminum alloys freeze in a mushy manner in sand molds. Solid particles form and grow in the center of the casting nearly as quickly and as rapidly as they do on the surface. One result of this type of solidification is that impurities, micro-segregates, gas (if present), etc., tend to precipitate at grain boundaries where they are most harmful to mechanical properties. Also, it is difficult to feed the solidification shrinkage of the last liquid to freeze in "mushy" alloys, because the interdendritic feeding channels become narrow near the end of solidification.

Mode of solidification is changed markedly by chilling. The rapid heat extraction caused by chilling increases cooling rate, and as a result refines the size and distribution of microsegregates and impurities at grain boundaries. Also, the steep thermal gradients caused by chilling make it possible to feed aluminum castings to complete soundness. Use of extensive chilling, in conjunction with other careful foundry techniques, makes it possible to guarantee high mechanical properties in aluminum alloy sand castings.

The somewhat different modes of solidification of different foundry alloys are responsible for many of the differences in foundry characteristics of these alloys. Fluidity, hot tearing and risering requirements

are all strongly affected by solidification mode. As one example, fluidity of pure aluminum (50 F above its liquidus) is approximately three times that of aluminum-4.5 per cent copper alloy (50 F above its liquidus); this difference in fluidity appears to be due almost entirely to differences in solidification mode. Similarly, resistance to hot tearing of pure aluminum is approximately three times that of the aluminum-4.5 per cent copper alloy, again due primarily to differences in mode of solidification.

Solidification under certain special situations has also been considered herein. For example, techniques have been described for producing castings with fully columnar dendritic structures, and for producing castings with complete absence of dendrites. Also, the effects of liquid and solid movement during solidification were described. Movement of liquid during freezing in chill molds can lead to tilted columnar grains and/or a banding type of segregation; in either sand or chill castings movement of liquid in the last stages of solidification (to feed solidification shrinkage) accounts for at least one type of inverse segregation.

APPENDIX

Nominal compositions of alloys referred to in text by their commercial designations*

	Mg, %	Si, %	Cu, %	Zn, %	Cr, %	Ni, %
43		5.0				
A132	1.2	12.0	0.8			2.5
195		0.8	4.5			
220	10.0					
355	0.5	5.0	1.0			
356	0.3	7.0				
40E	0.55			5.6	0.5	

*In practice these alloys are nearly always grain refined, generally by adding titanium in amounts up to 0.25 per cent.

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SOLIDIFICATION OF COPPER ALLOYS

by R. W. Ruddle

ABSTRACT

Commonly cast copper alloys may be divided into two main groups according to their mode of solidification. Group one freezes by the mechanism of skin or shell formation, and group two freezes by a pasty or mushy manner. The author considers both groups of copper alloys, dealing with pertinent data of each. Such data as alloying element effect, rates of freezing, alloy feeding mechanism, grain refinement and segregation effects are considered.

MODE OF FREEZING

Copper alloys as a group are particularly interesting from the point of view of solidification because they probably exhibit more variation in mode of freezing than any other group of alloys. From this point of view, the commonly cast copper alloys may be divided into two main groups.

Group One Alloys

Group one consists of copper which may be deoxidized or oxygen-bearing, aluminum bronze, manganese bronze, silicon bronze, certain yellow brasses of short freezing range, cupro-nickel and beryllium copper. These alloys freeze by the mechanism which is variously known as skin or shell formation. That is to say, freezing begins at centers on the mold walls, and the crystallites thus formed link up sideways and then grow forward into the hot interior of the casting. A solidification front thus separates the liquid and solid parts of the casting at all times during freezing.

This mode of freezing is shown in Fig. 1. It is important to note that the casting is essentially divided into two regions throughout solidification, a region of wholly solid metal and another region of fully liquid metal. In practice the mode of freezing depicted in Fig. 1 is only strictly true of a really pure metal—deoxidized copper would probably be a close approximation. It is a characteristic of the freezing of pure metals that there is a smooth and sharp boundary between the liquid and solid portions of the crystallites. In other words, the solidification front is a plane.

Most of the alloys of group one, because they are alloys and are not pure metals, do not exhibit a completely plane solidification front. Instead the front is somewhat serrated and contains hills and valleys, as illustrated in Fig. 2. Alloys showing this serrated type of front, providing the serrations are not marked, are not to be regarded as greatly differing from pure metals in solidification mechanism or in feeding characteristics, although, as discussed later, there may be some impediment to feeding. The mechanism of freezing in alloys in group one is essentially similar to that found in the freezing of many steels.

Group Two Alloys

Group two comprises alloys such as phosphor bronzes, gun metals, leaded gun metals or red brass, yellow brasses of long freezing range and the nickel silvers. In general, the mode of freezing of this group of alloys is totally different from that of the alloys in

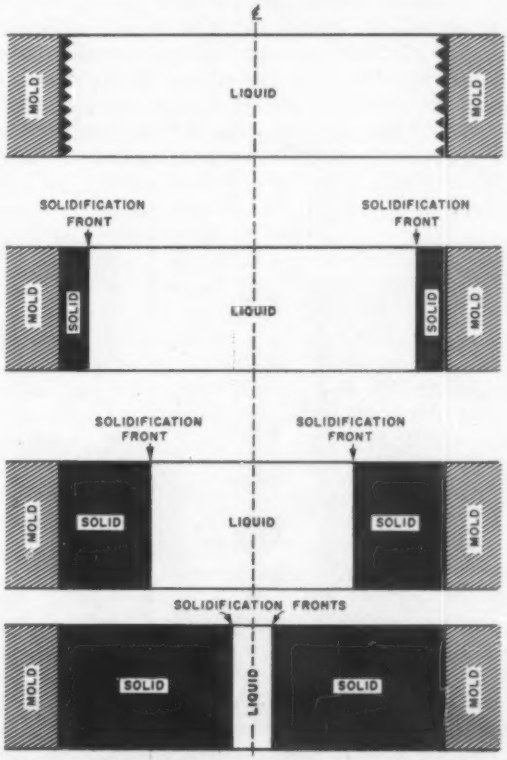

Fig. 1 — Mode of freezing of pure metals. Crystallization begins at the mold wall and advances into the casting interior on a plane solidification front.

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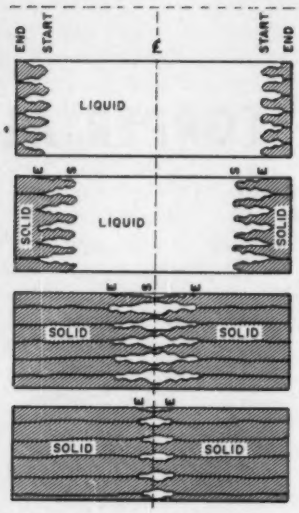

Fig. 2 — Mode of freezing of alloys of short freezing range (c.f., Fig. 1).

group one. As before, freezing begins by the deposition of crystallites of solid metal on the mold walls. However, once this has been accomplished, nearly all similarity in the mode of freezing of alloys in group one vanishes. The solid crystallites in alloys of this type are considerably impoverished in alloying elements because of the wide separation between the liquidus and solidus. As the result, when these crystallites form solute elements are ejected into the surrounding metal. This depresses the freezing point of the immediately adjacent liquid metal, as shown in Fig. 3, and results in growth of the crystallites is severely restricted.

The temperature of the whole casting then falls slightly (by perhaps a few tenths of a degree) and this causes a further crop of crystallites to form on whatever nuclei are available—suitable nuclei are nearly always present—at locations just outside the enriched zone. Growth of this second crop of crystallites is retarded as before, and as the result a third batch of crystallites is nucleated still further towards the interior of the casting (Fig. 3). This process repeats itself many times in a matter of a minute or so until crystallites have been nucleated throughout the entire casting.

Freezing then proceeds by the gradual enlargement of all the crystallites, this process taking place simultaneously throughout the entire volume of the casting as indicated in Fig. 4. The important characteristic of the pasty mode of freezing (Fig. 4) is that the casting is nowhere completely solid until the last stages of freezing, but throughout most of the freezing period consists of a mixture of liquid and solid. At first this mixture is fluid, the bulk of it being liquid and the solid crystallites representing only a small volume. After a little while when the crystallites have grown, the mixture, although still fluid, becomes sluggish and pasty.

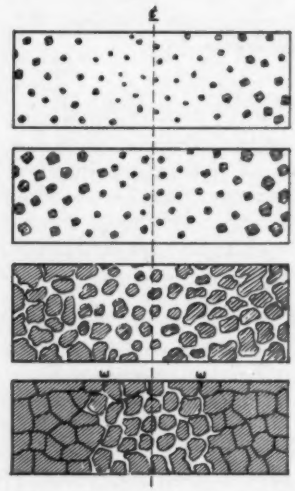

Fig. 4 — Mode of freezing of alloys of long freezing range.

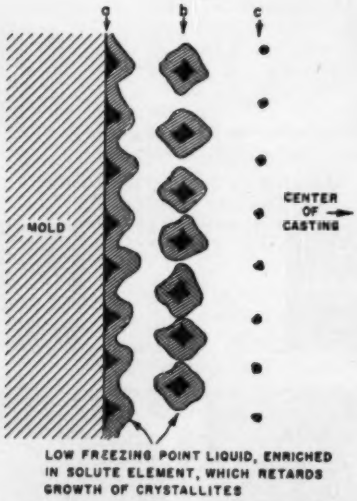

Fig. 3 — Mode of freezing of long freezing range alloys. a — crystallites form on mold walls, b — second crop of crystallites formed after growth of first crop is retarded, c — third crop of crystallites.

At a still later stage when the crystallites represent perhaps 70 per cent of the volume of the casting, they begin to adhere and interlock. At this stage the freezing casting begins to become rigid. This mode of freezing leads to a macrostructure composed of equiaxial crystals. For obvious reasons the crystallites close to the mold walls are somewhat larger than those in the center of the casting.

ALLOYING ELEMENT EFFECT

In practice, if we start from a pure metal and gradually add an alloying element, the mechanism of freezing changes imperceptibly from that shown in Fig. 1 through that depicted in Fig. 2 to that shown in Fig. 4. It is therefore true to say that there are really an infinite number of modes of freezing. In practice, some of the alloys of group two, at least under certain conditions, exhibit a mode of freezing which is inter-

mediate between the modes shown in Figs. 2 and 4. In the intermediate manner of freezing the growth restriction factor is not sufficient to completely stifle growth of the crystallites formed initially on the mold wall.

These in fact, are able to struggle forward towards the liquid core of the casting, but the growth restriction factor prevents them from linking up sideways until late in freezing. This mode of freezing is shown in Fig. 5. Freezing in this way is similar to the skin forming mode of freezing described earlier in that crystallite growth is largely columnar, although some equiaxial crystals may form in the central regions of the casting, as illustrated in Fig. 5. However, this type of freezing is more akin to the pasty mode of freezing in other respects, particularly in that for some considerable time there is no wholly solid or wholly liquid region in the solidifying casting.

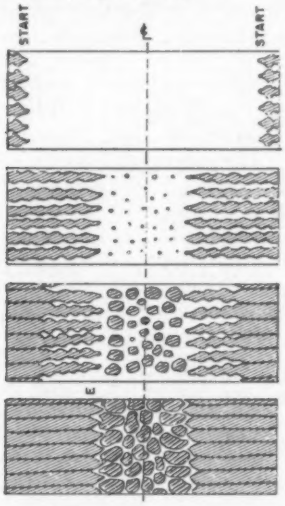

Fig. 5 — Intermediate mode of freezing of alloys of moderate freezing range (c.f., Figs. 2 and 4).

As mentioned earlier, certain copper alloys, particularly the tin bronzes, can show either pasty freezing or the intermediate type of freezing depending on the conditions of solidification. When freezing rates are fairly low, as with high pouring temperatures and thick sections, the tendency is towards the intermediate type of freezing. On the other hand, the pasty equiaxial mode of freezing generally takes place when freezing rates are high, as in thin sections or when the casting is poured with only a small superheat.

RATES OF FREEZING

Relatively little information is available on rates of freezing in copper alloy castings. It is probably true that less information is available for copper alloys than for either ferrous alloys or aluminum alloys. In the case of linear alloys not freezing by skin formation, the freezing rate may be well represented by an equation of the form $d = q\sqrt{t} - C$.* Unfortunately little

*In this equation d is the linear distance frozen (in in.) in time t (min); q is a constant known as the solidification constant and depends on the properties of the metal and mold; C is another constant governed mainly by the pouring temperature.

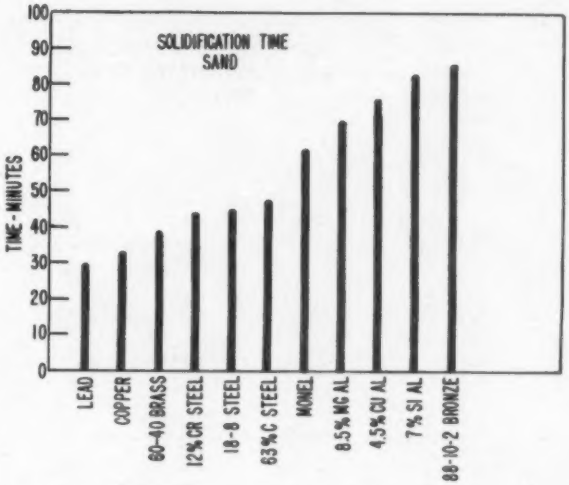

Fig. 6 — Solidification times of 7 in. square section castings in various alloys.

information is available on the value of q for copper and its alloys, although some years ago Ruddle and Mincher[1] obtained values of 0.27 in./min$^{1/2}$ for copper and for aluminum bronze. Pellini and his co-workers[2] have investigated the solidification times of a number of non-ferrous and ferrous alloys including copper alloys in 7 in. square sections and some of their results are reproduced in Fig. 6.

ALLOY FEEDING MECHANISM

The mode of freezing of an alloy generally has a profound effect on the mechanism of feeding and copper alloys are certainly no exception to this rule. In the case of alloys freezing by skin formation, the freezing shrinkage is normally compensated for by the formation of a central pipe. This pipe, in the case of a pure metal which freezes according to the ideal skin formation picture described above is perfectly symmetrical in shape, and indeed its shape may be described by mathematical equations.

However, most alloys of group one of practical importance, as mentioned earlier, do not quite fall into the ideal skin formation behavior, but the solidification front is serrated rather than plane. As the result, although a pipe forms much as in the case of a pure metal in the earlier stages of freezing, its surface tends to be rougher and less regular in shape. In addition, in the last stages of the feeding process, the dendrite tips may be left standing proud. As the result of this, the bottom of the funnel formed by the pipe tends to be somewhat ragged in shape.

On occasion there may be secondary pipe formed as the serrations, i.e., the dendrite tips tend to bridge across the narrow part of the funnel and obstruct the feed metal flow. This is of course, particularly prone to occur in the case of long castings and ingots, and this kind of shrinkage is often referred to as centerline shrinkage. In more complex shapes this mode of freezing tends to lead to a combination of centerline shrinkage with relatively large cavities at local heat centers as shown in Fig. 7.

The problem of preventing the formation of these cavities resolves itself into a matter of securing directional freezing so that the cavities are chased into the feeder heads.

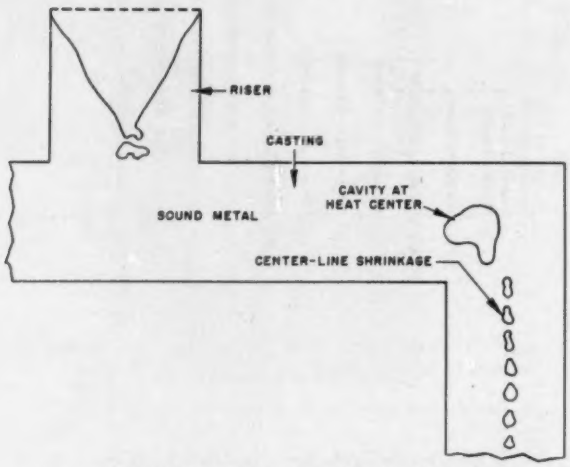

Fig. 7 — Shrinkage cavities in alloys by "skin formation."

Long Freezing Range Alloys

The mechanism of feeding in the alloys of long freezing range which freeze in the pasty manner is more complicated. During the early stages of freezing, while the metal in the mold is still substantially fluid, solidification shrinkage is obviously compensated simply by settling of the material in the mold. This process is known as "mass feeding."[3] As a generalization, it may perhaps be said that something like half the total freezing shrinkage is usually compensated for in this way. However, once the solidifying metal loses its fluidity and begins to set up as described earlier, this mechanism of feeding ceases to apply.

From this stage on the casting consists of a considerable number of growing crystallites which are quite large, between which there exist regions of liquid which are sometimes continuous and sometimes isolated. These channels are thin and tortuous at this stage, so it is easy to see that further feeding must be difficult. This is especially true when it is realized that all the solid crystals are competing for the available feeding liquid at the same time. No doubt some feeding does take place by movement of liquid down the tortuous interdendritic channels, but there is evidence to show that unless special methods are adopted to produce a high rate of freezing, for example heavy chilling of the casting or the use of exothermic materials, the extent of this type of feeding is small. Therefore, it is not surprising to find that commercial castings in group two frequently contain from 1¼ to 2½ per cent or more of dispersed porosity.

Typically, porosity in castings in alloys freezing in the pasty manner tends to consist of regions of coarse dispersed porosity in the heat centers, with finer

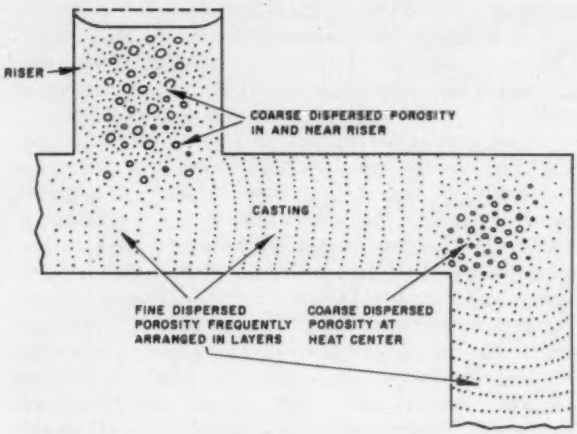
RISER
COARSE DISPERSED POROSITY IN AND NEAR RISER
CASTING
FINE DISPERSED POROSITY FREQUENTLY ARRANGED IN LAYERS
COARSE DISPERSED POROSITY AT HEAT CENTER

Fig. 8 — Forms of shrinkage porosity in sand castings in alloys which freeze in "pasty" manner.

porosity distributed throughout much of the rest of the casting, as shown in Fig. 8. This fine porosity may sometimes be in the form of layers, and may or may not be of the interconnecting variety.

The process of mass feeding which takes place in the early stages of freezing is normally aided by atmospheric pressure, which of course acts on the walls of the casting tending to oppose the formation of any cavities within the casting. For example, if a chunky casting is made in red brass without any feeders at all, it is interesting to find that the amount of shrinkage porosity is not particularly great. The reason is that atmospheric pressure has dished the walls of the casting, thus compacting the solidifying mass and aiding the mass feeding. If a small riser is attached to the casting only a slight reduction in porosity is accomplished, but much of the dishing of the walls is avoided (Fig. 9).

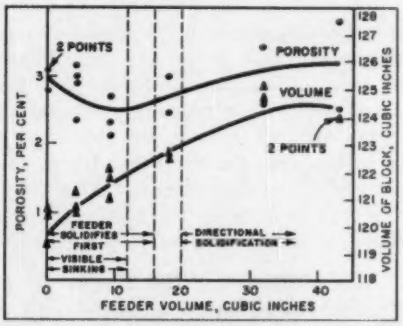

Fig. 9 — Plots of volume and porosity against feeder size of a 4 x 4 x 8 in. red brass casting made in a sand mold.

Surface Sinking Reduction

Increase in the size of the riser further reduces surface sinking (i.e., increases the volume of the casting) but has little effect on internal soundness as Fig. 8 shows. Use of large risers which will produce direc-

tional freezing actually decreases soundness.* The reason for this is that the casting and riser combined are now so massive that freezing is slow, as explained previously, and feeding is least efficient in these conditions. With these alloys the effect of a riser is therefore more one of pressurizing the plastic mass so as to fill out the mold cavity than one of improved feeding.

Alloys which freeze in the intermediate manner tend to exhibit feeding characteristics of both skin forming alloys and pasty freezing alloys. Shrinkage, although somewhat dispersed, is less so than in case of the pasty freezing alloys. There is quite a strong tendency for centerline shrinkage, or at least a central region of slightly dispersed shrinkage to form. In contrast with pasty freezing, where shrinkage is dispersed almost uniformly throughout entire sections of the casting, the walls of castings which freeze in the intermediate manner are generally almost fully sound, most of the unsoundness being concentrated in the central regions.

The probable reason for this is that the interdendritic channels in alloys which freeze in the intermediate manner are more open and feed metal is more readily able to flow down them. Castings freezing in this manner are therefore characterized by sound outer regions and unsound central cores. Unfortunately, the user of the casting is frequently prone to machine away the sounder metal on the outside and expose the porous material in the inner regions.

GRAIN REFINEMENT

In recent years the grain refinement of copper alloys has received quite a large amount of attention from research workers, and methods capable of refining the grain structures of most of the commercial alloys have been developed. The theory of grain refinement in copper alloys is much the same as that developed previously for aluminum alloys. The number of crystals, and hence the grain size, depends upon the number of nuclei for crystallization present in the melt when it is poured and a reduction in grain size can be secured by artificially increasing the number of these nuclei.

To do this it is necessary to generate in the melt small, almost sub-microscopic particles of compounds which, by reason of registry of their crystal structure with that of the alloy which is being cast and by virtue also of similarity in the type of interatomic bonding, are readily able to initiate the solidification of crystallites of the alloy. Once this theoretical background had been established for aluminum alloys, it did not prove to be a particularly difficult matter to find additives which could be made to copper alloys, and which would form in the melt nuclei of high melting point possessing the required crystallographic characteristics.

Several methods of grain refining copper alloys were thus developed, for example use of zirconium in 0.05 per cent quantity with bronzes, gun metals and red brass and the use of iron in about 1 per cent

*This statement applies to castings of heavy section but is not necessarily true of thin sections.

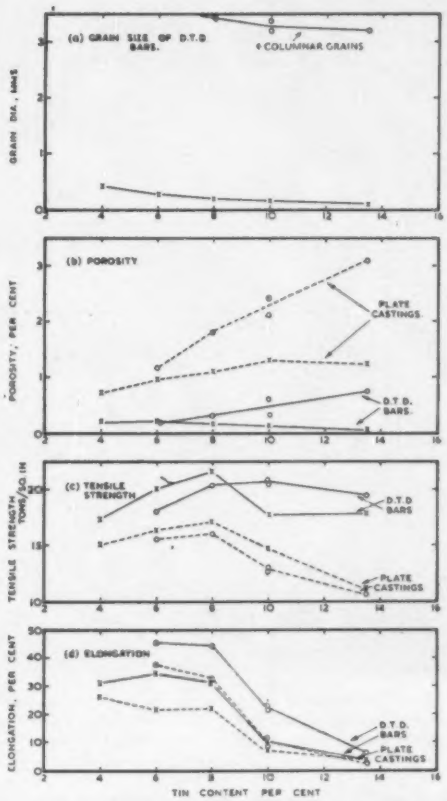

Fig. 10 — Effect of 0.06 per cent addition of zirconium on grain size porosity, tensile strength and elongation of gun metal castings containing 2 per cent zinc poured at 2100 - 2160 F. o——o, unrefined; x——x, refined with 0.06 per cent zirconium additions.

quantities in the same alloys.[4] Iron also refines the grain of aluminum bronzes and manganese bronze, and as this element is frequently present in the alloy for other reasons, grain size is usually fine. Iron-free aluminum bronzes and beta brasses can be refined by the addition of zirconium (0.03 per cent) and boron (0.02 per cent) or by boron alone.[5] Other elements, such as rare earth metals, are also effective as grain refiners.

Strength Improvement

In the case of iron-free aluminum bronzes, these grain refining techniques produce a useful improvement in strength. The effects of grain refinement in bronzes and gun metals are more complex. Some improvement in strength and soundness is usually produced in well-fed castings which do not develop large amounts of shrinkage porosity, as Fig. 10 shows. However, the majority of bronze, red brass, gun metal castings are not especially well fed, and attempts to improve the strength and feeding of poorly fed castings have been fruitless. Some efforts may even produce a deterioration in pressure tightness.

Figure 11 shows the distribution of porosity in a test casting made without any special refining treatment so that the structure was relatively coarse grained. As can be seen, some dispersed porosity is

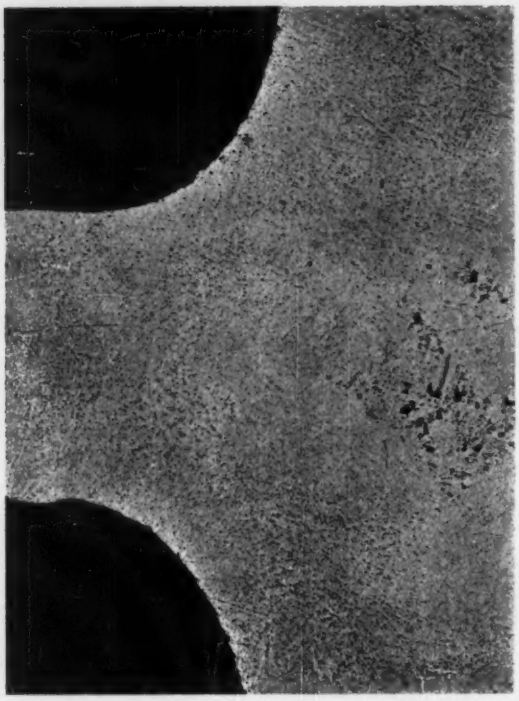

Fig. 11 — Distribution of porosity in a cross grained lead brass casting poured at 2120 F (finest particles are mainly lead). 5 ×.

evident, together with fine lead particles in the outlying regions. However, the porosity is mainly concentrated in the central regions of the casting, and microscopical examination showed that it is not of the interconnecting variety. Figure 12 shows the same

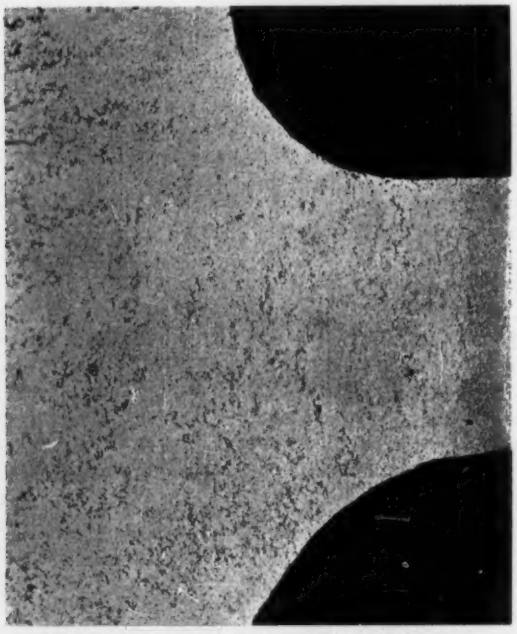

Fig. 12 — Distribution of porosity in a zirconium refined casting in lead brass poured at 2100 F. Note severe layer porosity (finest particles are mainly lead). 5 ×.

casting made in the identical alloy after grain refinement. The grain refinement has markedly altered the distribution of the porosity which is now finer and more widely dispersed. However, worse than this is the fact that the microporosity now tends to be arranged in layers and is of the interconnecting variety as the result.

This kind of porosity, sometimes known as "layer porosity," is not infrequently met with in certain aluminum alloys. As the result, in many cases where grain refinement is applied to castings which are essentially poorly fed, i.e., those which contain one per cent or more porosity, the natural effect of grain refinement is to markedly reduce pressure tightness. For this reason it does not appear that grain refinement is generally useful with bronzes and similar alloys. A fine grained structure can also be produced in bronze castings by pouring at a low temperature. Because of the harmful effect of this structure, this practice should generally be avoided at all costs.

On the other hand where a casting is known to be well fed and to be almost completely sound on solidification (a thin bar or plate might be an example of this class of casting), grain refinement may produce a useful increase in mechanical properties.

SEGREGATION EFFECTS

Space precludes any detailed amount of segregation effects in sand cast copper alloy castings, but is perhaps worth mentioning that the type of segregation found is closely connected with the mode of freezing. Alloys of group one, which freeze in the skin forming manner, as might be expected usually show normal segregation. In sand castings the extent of this is seldom marked and is usually negligible. Castings made in alloys which freeze in the pasty manner, on the other hand, will frequently tend to show inverse segregation and even blebbing on the surface. "Tin sweat" is the commonest example of this kind of segregation. The reason for this type of segregation in alloys which freeze in the pasty manner is obvious. Until almost the end of the freezing process there are local regions on the surface of the casting which maintain a liquid connection with the interior of the casting, and clearly if gas evolution takes place in the final stages of freezing there is every chance that metal can be forced through these channels to the surfaces of the casting. Furthermore, at this stage such residual liquid as exists in the casting will be highly enriched in alloying elements, so that when conditions are suitable a marked degree of sweating and inverse segregation may be present.

ACKNOWLEDGMENT

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SOLIDIFICATION OF METALS

A Summary

by W. K. Bock

ABSTRACT

This is the summation paper of the solidification symposium. Its intention is to bring theory and practice together. The problem of solidification is complex and the factors involved are not always independent of each other. The total symposium has presented the basic ideas and the present-day accumulated experience in the field. From a foundry viewpoint, the main factors toward desirable grain structure means a careful selection of mold material, mold density, pouring temperature, selection and location of exothermic compounds and use of foreign body nuclei.

INTRODUCTION

The preceding papers of this symposium have dealt with the modern concepts of the solidification process, and with the solidification of the alloys of greatest commercial significance. The purpose of this summary is to bring theory and practice together. Generally, we would like to eliminate or at least minimize the columnar structure and have castings freeze with equiaxed grains. Most of the time we would like to have a small grain size. How to obtain this result is the object of these papers.

Although risering is not a subject for this series of papers, solidification shrinkage makes it necessary to notice the problem of feeding. Skin forming alloys, particularly when columnar structure obtains to considerable distance, are liable to centerline shrinkage, and pasty freezing alloys are subject to microshrinkage. Since the solution to the shrinkage problem depends on the type of the defect which, in turn, depends on the mode of freezing, these papers furnish a starting point for risering studies.

Mold material is another topic which is beyond the scope of this symposium, but since the mold is the heat sink whose thermal behavior controls the thermal conditions in the casting, and since the mold wall in some instances furnishes nuclei for solidification, the mold material cannot be neglected. The same can be said about chills and exothermic compounds.

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We may consider that the process by which metal transforms from liquid to solid is divided into four steps:

1) Cooling to liquidus temperature.
2) Undercooling.
3) Nuclei formation.
4) Crystal growth.

At any point in the casting, the metal goes through these four stages in order, but when it does so depends roughly on how far the point is from a mold wall. At a given moment of time all four stages may be going on in a casting, each at a different location.

COOLING TO LIQUIDUS TEMPERATURE

As the liquid metal in the mold cools, it eventually reaches the liquidus temperature. This is the highest temperature at which solid can form. From a thermodynamic viewpoint, it is the temperature at which the free energy of solid is equal to the free energy of liquid. Figure 1 schematically shows the free energy curves for liquid and solid as functions of temperature. The stable phase at any temperature is that which has the lower free energy. If equilibrium was obeyed, the metal would be liquid to the liquidus temperature and solid below. It has been mentioned in several places that this does not happen, and metals undercool to a measurable extent before freezing begins.

The reason for this departure from equilibrium is not difficult to explain. In the liquid, each atom moves rather freely and almost independently of other atoms. In the solid state, it has restricted movement at a prescribed position in the space lattice. In a pure metal, the transformation from liquid to solid involves complicated atomic rearrangement. Such a change could easily involve the need for driving force plus possibly some triggering mechanism.

When a solid solution is formed, the solute atoms might constitute 10 per cent of the atoms in the liquid, for example, and the solid which precipitates might have only five atomic per cent of solute. Thus, in freezing solid solutions, there are not only the

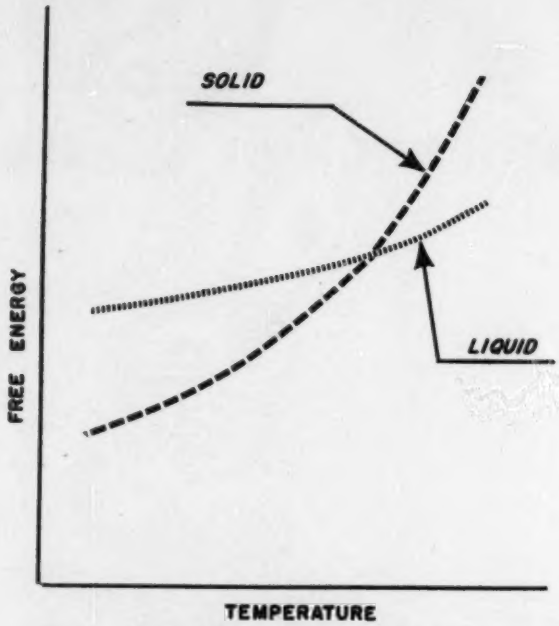

Fig. 1 — Schematic diagram showing free energy curves for liquid and solid as functions of temperature. The free energy difference between liquid and solid increases with increased undercooling.

problems associated with atomic rearrangement, but also the problem of selecting the proper number of each atomic species from a mixture in which the proportions of atoms are different.

The solidification of eutectics represents a bigger problem, since two or more solid solutions must freeze together.

It is safe to say that cooling to the liquidus temperature is a necessary but far from sufficient condition for solidification.

UNDERCOOLING

It is common practice in discussing solidification to refer to the alloy diagram or to equilibrium conditions. This is satisfactory for purposes of exposition, but cannot present a true picture because undercooling is always present and must be considered in real problems.

Undercooling can come from two different causes. Natural undercooling occurs because the temperature of the liquid falls continuously and, as mentioned above, solidification does not begin at the liquidus temperature. Natural undercooling can be increased by speed of cooling. If cooling is fast enough, as in a thin section, undercooling may be 150 degrees or more.

Constitutional undercooling is caused by the precipitation of solid solutions. This is explained by reference to Fig. 2. The diagram at the top of the figure is the usual equilibrium diagram, and it is assumed from the diagram that if solid is formed at temperature *T*, the remaining liquid is enriched in solute because the solute content of the solid is less than that of the liquid from which it came. Unless diffusion or mixing occurs rapidly, the concentration of solute is high at the solid-liquid interface, and decreases to the liquid composition at some distance from the interface, as shown by the middle graph.

Reference to the liquidus line of the upper chart shows that the liquidus temperature increases as the amount of solute in the liquid decreases. So, using the composition-distance curve, we can plot the indicated liquidus temperature at each distance from the crystal face. The resulting curve is marked "liquidus" in the lower diagram. If the temperature gradient over the same distance is shown by the line marked "gradient," there exists a region, shown by the crosshatching, where the metal is undercooled due to the mechanics of solidification of solid solutions.

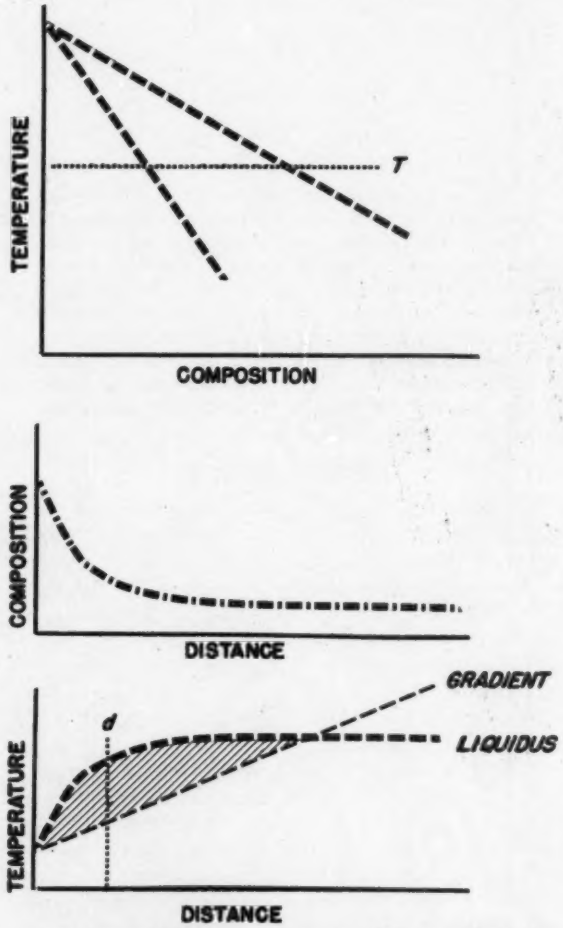

Fig. 2 — Schematic diagrams showing constitutional undercooling is caused by precipitation of solid solutions. *Top* — usual equilibrium diagram. If solid is formed at temperature *T*, the remaining liquid is enriched in solute because the solute content of solid is less than that of the liquid from which it came. Liquidus line in upper chart shows that liquidus temperature increases as the amount of solute in the liquid decreases. *Center* — composition-distance curve used to plot indicated liquidus temperature at each distance from the crystal face. *Bottom* — curve resulting from using center chart is marked "liquidus." If the temperature gradient over the same distance is shown by line marked "gradient," lined area is where metal is undercooled due to mechanics of solidification of solid solutions.

Later, it will be shown how constitutional undercooling can cause solidification to change from columnar to equiaxed type.

Figure 1 shows that the free energy difference between liquid and solid increases with increased undercooling. Thus, the driving force for the transformation increases with undercooling. It does not matter whether the undercooling is natural or constitutional. Undercooling is a necessary and sometimes sufficient condition for solidification.

NUCLEI FORMATION

It is necessary to recognize two classes of nuclei; self nuclei and foreign body nuclei. Foreign body nuclei have the lattice structure and atomic bonding which permit the freezing metal to attain its natural lattice configuration by building onto the nucleus lattice. Self nuclei are formed from the melt by some statistically governed process. The rate at which these nuclei, form or the number formed in a given time, is related to the amount of undercooling. Free energy considerations might suggest that the rate of nucleation would increase monotonically with increased undercooling, but the Tammann curve of Fig. 3 shows the relation which does obtain. Rate of nucleation increases to a maximum and then decreases with increased undercooling. Some finite amount of undercooling is necessary for any nucleation.

Self nuclei would be relied on for homogeneous nucleation and, it has been said that heterogeneous nucleation is far more important in freezing of castings. However, self nuclei do play important roles in explaining two observations which have been made on the freezing of solid solutions.

It has been noted that certain alloys, notably the light alloys with long freezing range, solidify by the pasty mode when cast in sand and by the intermediate mode when chill cast. Also, it has been noted that certain skin forming solid solutions like steel freeze to a certain depth with columnar crystals and then solidify as equiaxed crystals. Self nuclei seem to be important in both cases.

When an alloy freezes in the pasty condition, the number of nuclei per cu in. or cu mm appears to be about the same in every part of the casting. In the intermediate mode of solidification, there are more nuclei adjacent to the mold wall. The change from pasty to intermediate freezing occurs when the mold is changed to remove heat faster. Figure 4 shows the conditions schematically. As shown in the upper part of the figure, there is comparatively little undercooling in the sand mold even at the mold wall. This places the point in Fig. 3 far to the left, showing a comparatively low rate of self nucleation which is almost the same throughout the casting. Obviously, most of the nuclei are foreign body type and self nuclei can be neglected.

Foreign Body Nuclei

In the chill mold, the number and distribution of foreign body nuclei should be about the same as in sand casting. In order to freeze in the intermediate manner, the number of nuclei close to the mold wall must be increased, as indicated at the bottom of Fig. 4.

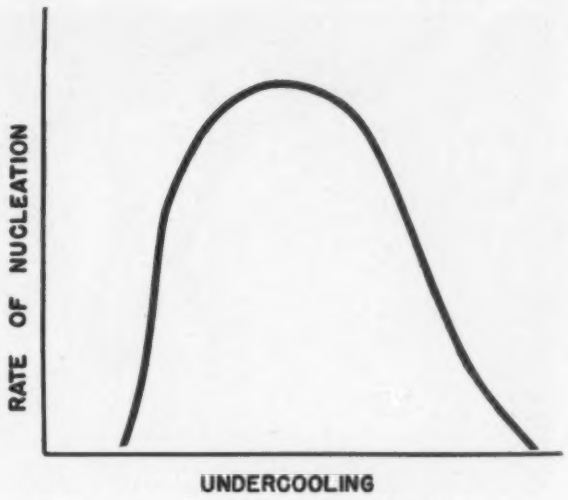

Fig. 3 — Tammann curve showing relationship between undercooling and rate of nucleation.

The cooling rate and therefore the undercooling is greater in the chill mold, as indicated in Fig. 4, and according to the Tammann curve, the number of nuclei should be greatly increased close to the mold wall due to increased rate of nucleation. Since foreign body nuclei apparently are not "borrowed" from the

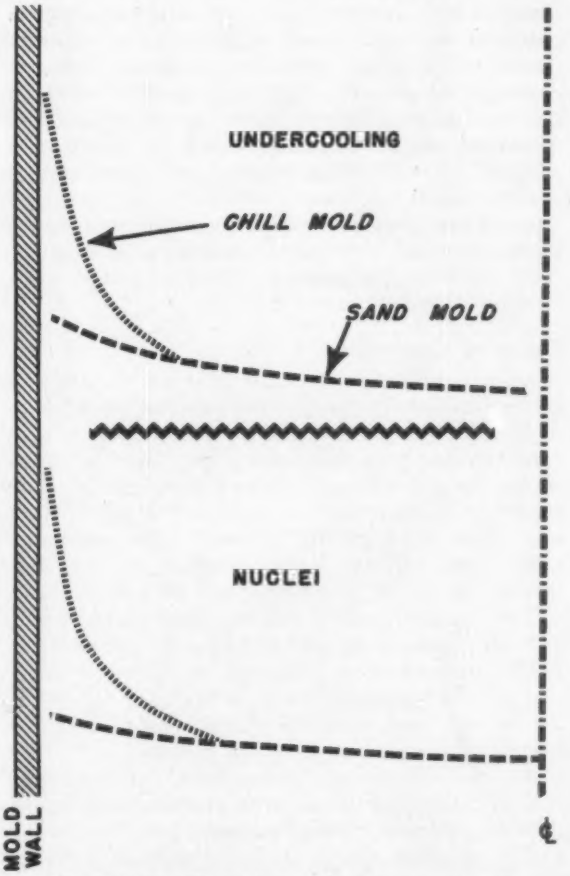

Fig. 4 — Change of mold conditions to promote faster heat removal effect on cooling rate.

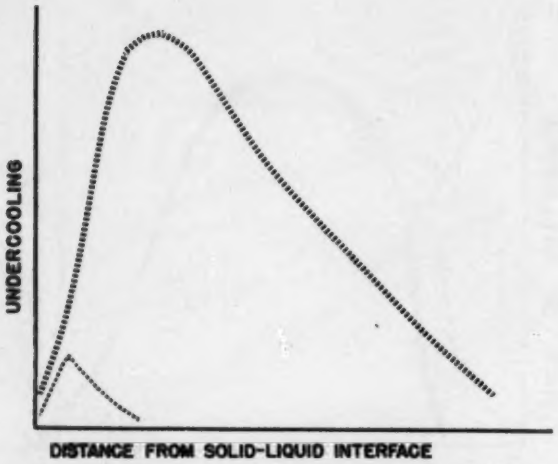

Fig. 5 — Plot showing undercooling as function of distance from interface (short curve). As columnar growth proceeds, solute concentration at the interface increases which leads to greater constitutional undercooling-distance curve increases in height and extent (large curve).

interior of the casting to help in skin forming, the increase in nuclei must be self nuclei generated by the undercooling.

It was noted above that constitutional undercooling could cause the solidification of solid solutions to change from the columnar to equiaxed type. Consideration of Fig. 2 will show that the amount of undercooling will vary with distance from the solid-liquid interface, and will be a maximum at some distance *d*. As indicated by the Tammann curve, there is a certain amount of undercooling required before self nucleation can begin.

With these two observations, we can consider the process by which columnar crystals form to some distance and then give way to equiaxed crystals as in the freezing of steel, for example.

Columnar Crystallization

At the start, when the chill layer has formed and columnar crystallization has not gone far, the buildup of solute at the solid-liquid interface is not great and constitutional undercooling is slight. Plotting undercooling as a function of distance from the interface would give a curve like the short one of Fig. 5. However, as columnar growth proceeds, solute concentration at the interface increases much in the same manner as it does in a single pass in zone refining.

This leads to greater constitutional undercooling, and the undercooling-distance curve increases in height and extent, as indicated by the larger curve of Fig. 5. When undercooling is sufficient self nuclei are formed, and equiaxed crystals begin to appear ahead of the advancing columnar crystals.

According to theory, heterogeneous nucleation by foreign bodies should be more effective than homogeneous nucleation. Modification of gray iron and of aluminum alloys furnish many examples of deliberate increase of heterogeneous nucleation. However, it was shown above that homogeneous nucleation is of more than theoretical interest, since it produces important practical effects.

CRYSTAL GROWTH

Crystal growth is probably the most complicated step of the solidification process. Some of the factors involved can be manipulated in casting and some cannot, so there is a degree of uncertainty in this step of the solidification process. Crystals grow by the process of having atoms in the liquid attach themselves to an existing nucleus or crystal. This process extends the existing space lattice. There are varying degrees of attraction for the added atom. An atom at a corner will attract the atom from the liquid more strongly than an atom on an edge and the latter will exert more attraction than an atom on a plane. Moreover, atoms on certain crystallographic planes have more attractive force than those on other planes.

The latter observation explains the reason why rate of growth is different in different crystallographic directions. This, in turn, gives part of the explanation for the development of columnar crystals.

Recent findings have shown that growth process of crystals is a little different from that indicated above. In 1945, Dr. H. A. Schwartz, in the annual Foundation lecture of A.F.A., showed the picture of bismuth crystals which is reproduced here as Fig. 6. This mass was found after the mold broke in casting and bled off the liquid bismuth. At the time, Dr. Schwartz noted the direction of the cube diagonals perpendicular to the mold surface and the near perfection of the cubes being formed.

In the light of knowledge gained since 1945, we now notice that the crystals are built up of steps or terraces, and that in some places where the cube face is almost plane these steps form a sort of spiral. Atoms seeking to attach themselves to the solid will be attracted by these steps, and tend to fill them in and yet retain some vestige of the spiral pattern. This can lead to the generation of a screw dislocation, which was mentioned briefly by Form and Wallace. These screw dislocations form a step on a crystal face and so facilitate deposition of atoms. This type of dislocation has become regarded as almost a necessary condition for crystal growth.

It can be seen that if crystal growth is reduced to its fundamentals the factors involved are not subject to control by modern foundry technology, but crystal growth can be controlled by indirect means.

Heat of Fusion

One thing that must always be remembered in considering crystal growth is the fact that as solidification proceeds, the latent heat of fusion is released continuously. If this heat is not removed, it can raise the temperature of solid and surrounding liquid to the value where freezing stops. Removal of this heat requires a temperature gradient. Of course, the local release of heat of fusion creates a temporary hot spot which tends to cause a gradient in all directions.

This is not completely satisfactory, because heat follows the gradient and some of the heat of fusion would heat the liquid, thus destroying the conditions

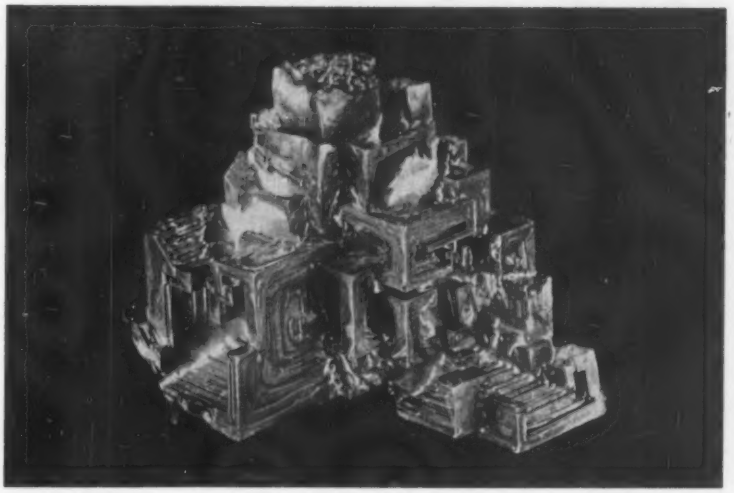

Fig. 6 — Bismuth crystals mass found after mold broke in casting and liquid bismuth bled off by Dr. H. A. Schwartz in 1945.

for nucleation and further crystal growth. Temperature gradients must exist so that the latent heat of fusion flows into the already solid metal and then into the mold.

When such a temperature gradient is established, it has a further effect on the direction of crystal growth. It has been noted in several places that columnar crystals grow along a line of temperature gradient. It has been shown that when steep gradients exist there is some undercooling, and this also affects the rate of grain growth. The Tammann curves, one of which was shown in Fig. 3, are commonly published in pairs as in Fig. 7. It can be noted that the rate of growth curve like the rate of nucleation curve passes through a maximum. Whether this is a direct result of the relation between rate of liberation of latent heat of fusion and rate of disposal of this heat or is some result of undercooling itself might be argued. For the foundryman's present purpose, the observation is far more important than the mechanism.

Columnar crystals are not desirable, and so it is useful to examine their growth. If cooling rate is slow due to too mild a temperature gradient the crystals grow in a preferred direction, and the buildup of solute in the liquid has time to level out thus preventing constitutional undercooling and the resulting nucleation of equiaxed crystals. This merely results in segregation in the center of the casting. On the other hand, fast cooling results in fast growth in the direction of the steep thermal gradient, and does not give time for nucleation of equiaxed grains to occur or to be effective. There exists for any alloy an intermediate range of thermal gradients and cooling rates, which are most conducive to equiaxed structures.

Dendritic solidification is another thing which must be watched. High rates of freezing, and slight temperature gradients in the liquid, favor dendritic formation.

CONCLUSION

It is not possible to give detailed solution of the problem of how to obtain a fine equiaxed grain structure in a given casting. However, principles are known and can be used in studying the problem. Probably each casting is a separate problem.

The main factors leading toward desirable grain structure are:

1) Relatively fast cooling.
2) Proper temperature gradient.
3) Artificial nucleation.

From a foundry viewpoint, this means careful and perhaps ingeneous selection of mold material, mold density, pouring temperature, selection and location of exothermic compounds, use of foreign body nuclei.

The problem of solidification is complex and the factors involved are always not independent of each other. This symposium has presented the basic ideas and accumulated experience in the field. Further advances may not be easy, but the papers presented here may make it easier because they place present knowledge and practice in one place.

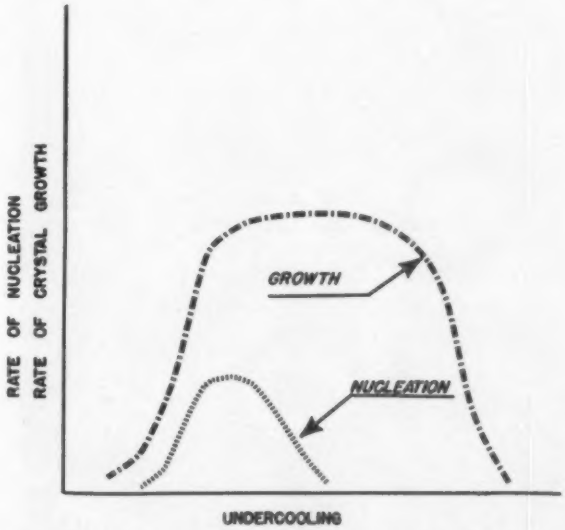

Fig. 7 — Tammann curves showing rate of nucleation curve and rate of growth curve.

MAGNESIUM FOUNDRY PRACTICE DEVELOPMENTS

by J. House

ABSTRACT

Many advances have been made in magnesium founding techniques in the last several years. Included are the ability to make larger, thinner and more dimensionally precise castings. Sand technology has expanded to include sodium silicate carbon dioxide and shell cores and waterless molding sands. Techniques for casting in inserts and for developing intricate passageways have become commonplace.

New alloys have been developed that allow higher temperature applications and higher strength applications at both room and elevated temperatures. Quality control techniques have expanded to allow even more consistent high quality castings.

INTRODUCTION

Recent developments in magnesium foundry practice have been in the direction of taking fuller advantage of the outstanding castability of these alloys. There has been a continued broadening of the design ranges which have come to be regarded as feasible for magnesium foundrymen to handle. From the extremely large to the extremely small; from the highly intricate and thin-walled to the massive castings, magnesium alloys have proved themselves to have the necessary versatility to do many varied jobs. The following points out some of the various design range "frontiers" in which progress has been made in recent years.

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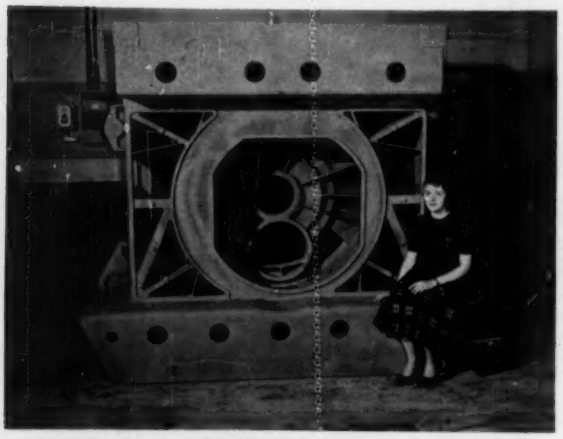

Fig. 1 — 1450 lb Nike-Hercules system casting.

LARGE CASTINGS

Figure 1 shows the Nike-Hercules base casting that is a vital component of the ground control system for guiding this missile. This 1450 lb casting has now been made by three different magnesium foundries, showing that the maturing magnesium casting industry is capable of offering multiple sources for even the more difficult parts.

The design of the part makes it necessary to use a large number of massive dry sand cores for the forming of the numerous box-like compartments that are incorporated in the design. The conventional way of producing the coring for these box-like compartments would be to split the coring at some convenient level with a horizontal parting line. Each of the two resulting cores would thus be made in a dump box on a flat core plate.

These two half cores would then need to be "rubbed" in a rub jig or core grinder to compensate for the slumpage of the cores prior to and during baking. These rubbed half cores would then need to be assembled to form the complete coring for the compartment.

In the CO_2 process a way was seen first, to avoid much of the labor involved in this conventional practice, and second, to achieve improved dimensional accuracy in the finished core. A third dividend from the use of the CO_2 process was the savings of sand realized by making the core hollow. Figure 2 illustrates various stages of the making of these cores.

Figure 3 shows the cope pattern, and in the background the molder is finishing the copy. Figure 4 shows the mold being closed. Note the steel k-frame (there is no cheek mold) that supports the cope at the proper height. Note also the clamps that hold the hollow CO_2 sand cores in and keep them from being forced apart by the internal pressure of the metal when it is poured into the mold.

This mold was poured from six 750 lb capacity crucibles, four of which were poured at a normal temperature, and two of which were poured into the risers at a higher casting temperature.

CORE PROCESSES

At the other end of the size scale, investment castings, some weighing only a fraction of an ounce,

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Fig. 2 — As-gassed core with dummy blocks removed.

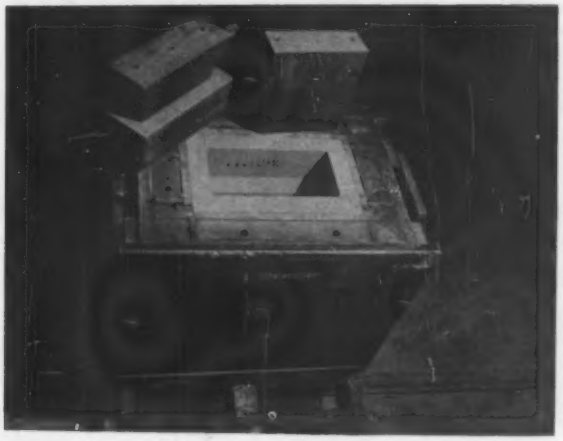

Fig. 3 — View of cope pattern and cope mold.

Fig. 4 — Closing Nike-Hercules base casting mold.

are being regularly cast by several foundries. Another design range where attention to minute detail has been required is in the field of wave guides for radar equipment. In this field, too, several foundries have demonstrated skills bordering on the unbelievable. Wave guide passages are specified to tolerances of ± 0.005 in. or less, and with surface finishes as fine as 63 micro-in.

To achieve tolerances of this kind, (as we did in making the huge Nike base casting) the practical value of processes by which the core can be hardened in the core box are encountered. The conventional practice of removing the green core from the box, then imparting its final strength by a baking operation, is simply not adequate to achieve extreme precision reproducibly. There is a great need for developing other economical binder systems similar to the CO_2 process that will allow cores to be hardened in precision core boxes.

Preferably, such systems should not require heating of the core box, with the attendant dimensional changes that such heating produces, although many wave guide cores have been made in this manner, that is, by baking the core in the box. The CO_2 process itself has three major disadvantages:

1) Poor collapsibility of the core.
2) High tendency for gas evolution from the binder, which requires a relatively high permeability base sand in order to avoid blows.

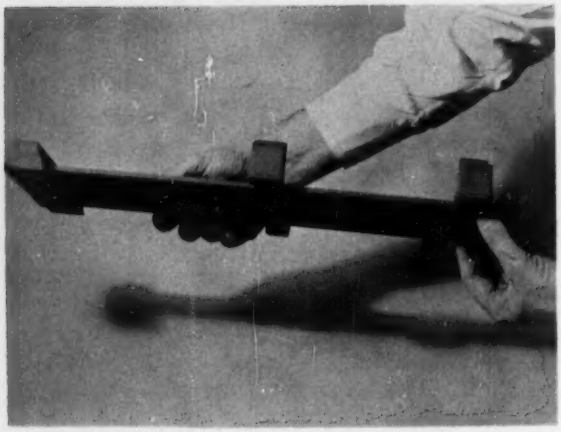

Fig. 5 — Shell core.

3) Relatively poor surface finish of a water-glass bonded core as compared with either an oil sand or a resin-bonded sand of comparable base sand fineness.

Development of a binder system that would allow quick hardening of the core in the box, while avoiding these disadvantages, would permit further substantial advances in the production of reproducibly precise castings.

Shell Core Process

One process that permits hardening of the core in the box is the shell core process. By this process, a sand coated with phenol-formaldehyde binder is introduced into a heated metal core box. Flow of heat from the box into the sand produces a hardened shell on the core. When a sufficient shell has formed to impart rigidity, the excess, unhardened sand is dumped out. The resulting shell core is removed from the box.

This process shares some of the disadvantages of the CO_2 process, especially the relatively poor collapsibility or breakdown characteristics of the binder. Distortion of the core box equipment and of the cores due to the large temperature cycles involved also militates against the extreme dimensional precision that is attainable with cold processes. However, the shell process has some decided advantages that make its use highly logical for some applications.

First, good surface finish, stemming from excellent core surface hardness, is attainable, making possible the production of strong cores capable of withstanding rough handling, even in design ranges having high length: cross-section area ratios. A third advantage of the process is the relative ease with which long cores of small cross-sectional area can be made. The extreme flowability of the coated sands allows cores having small cross-sections to be blown full and firm with simple rigging and equipment.

Figures 5 and 6 show a number of typical shell cores that have been made in the author's company's foundry. It is doubtful whether some of these designs could have been made successfully on a production basis by any other available process.

CAST IN PASSAGEWAYS

As the necessary foundry skills become more wide spread, designers are taking increasing advantage of the possibility of incorporating long passages of small cross-sectional area in castings. Previous figures have shown examples wherein the shell core process is useful in this design area. Other processes are now available, on a license-arrangement basis, whereby even smaller diameter passages of yet greater length can be successfully produced.

Figure 7 shows a part incorporating both shell cores and special passage cores for the circulation of cooling fluids through the walls of an instrument housing. Castings in this design range are now produced on a routine production basis by several magnesium foundries. Development of these techniques has long since passed the stage where it is to be regarded as a "trick-molding" job; the techniques are now a production practice.

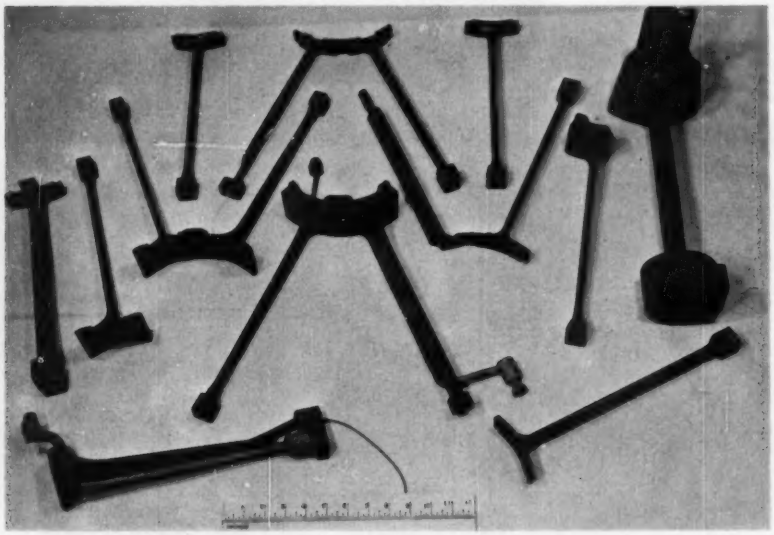

Fig. 6 — Shell cores.

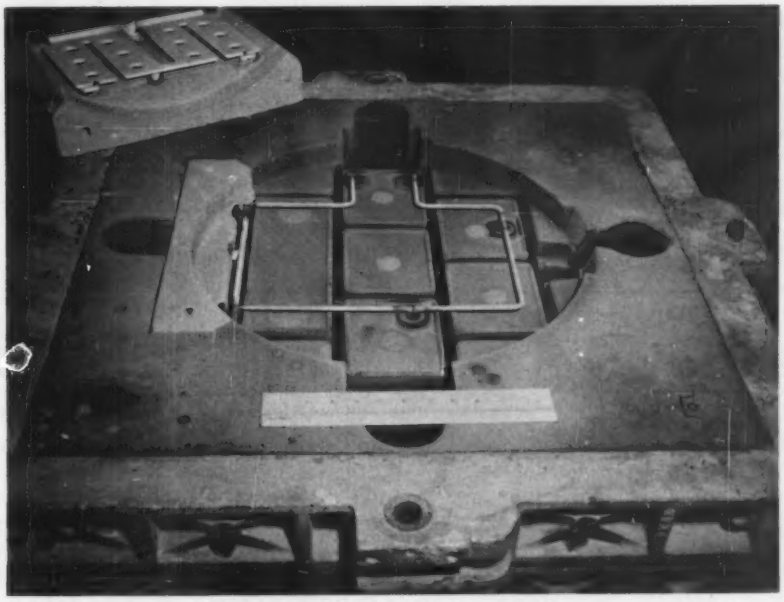

Fig. 7 — Mold half showing special cores and shell core in places. Assembly at upper left is identical to that which is in place in left side of mold.

The casting-in of stainless steel or other metal tubing is, of course, another practice that can be, and is, used extensively to aid and abet the designer in simplifying the problem of transferring fluids from one location to another in cast assemblies.

THIN WALL CASTINGS

Another "design frontier" on which important advances have been made in recent years is in the casting of thin wall parts. This frontier was pioneered by certain West Coast magnesium foundrymen, who exploited the exceptional castability of magnesium alloys to satisfy the design needs of the airframe industry. These efforts demonstrated the feasibility of producing parts with much thinner walls than had previously been considered practical. Today, numerous magnesium foundries throughout the country are offering castings in the thin wall design range.

While there has been a great deal of publicity describing the design characteristics of thin wall parts that have been produced, there has been little disclosure of the specific techniques employed to achieve these results. One notable exception to this generalization is the quite recent discovery at M.I.T. of the value of hexachloroethane as a fluidity spray for aluminum alloys. The work done with magnesium has confirmed the published results, indicating that this mold surface preparation has a decided effectiveness in improving the apparent fluidity in thin sections of magnesium alloys cast into sand molds.

There is a relatively new practice of chemically milling magnesium alloys. This allows selected areas to be reduced in thickness chemically, which lets the foundryman cast sections that are not misrun prone. This gives the designer a new range of thin sections, without the penalty of poor casting efficiencies.

MOLDING SAND

Another rather recent development that shows great promise is the development of waterless molding sands. One with which the author's company has had production experience is a modified form of bentonite, which derives its bond strength from oil as a tempering medium rather than water. The company believes this development has significance for magnesium. It makes sense to keep water away from molten magnesium, from the point of view of avoiding reaction. Even more significant than a reduction in the amount of needed inhibitors, are the other benefits conferred by the absence of water.

First, this sand has much better flowability than water tempered sand. Also, since the oil used to temper the sand is much less volatile than water, much less gas is generated when the molten metal contacts the sand mold. There is, hence, less need for as high mold permeability. This permits the use of finer base sands, which give superior casting surface smoothness without encountering blow-type defects. Another dividend accruing from the low volatility of the tempering oil is the prolonged shelf life of the molding sand heap.

The heap remains moldable for literally weeks without any special protection against exposure to the atmosphere. However, some disadvantage must be scored against the waterless sand in a complete appraisal of it. For high production of heavy section castings, excessive sand temperatures can develop unless adequate provisions are made for cooling the sand heap. Also, the excellent retention of green strength that results from failure of the sand to "dry

out" is not an unmixed blessing. It makes for difficulty in screening the sand for removal of lumps of core sand, pieces of metal and other foreign materials that chance to get mixed with it.

For these reasons, the adoption of waterless sand may complicate the mechanical sand handling equipment appropriate for high production work. These mechanical difficulties, plus the rather high price of this binder, may tend to retard the wide-spread adoption of this type sand. But it is the author's company's feeling that the technical advantage to be gained will outweigh these considerations, and that this type of sand has great promise for the future.

ALLOY DEVELOPMENT

Mention should also be made of the progress in recent years in the development and application of new alloys. Not too many years ago, the Mg-Al-Zn family of alloys were the only magnesium casting alloys of any commercial significance. The widespread use of the rare earth zirconium-containing alloys, such as EZ33A, while hardly in the category of recent developments, perhaps deserves mention. These alloys have proved useful where elevated temperature problems are encountered. The excellent pressure tightness of these alloys has led to their extensive use where this factor alone has governed alloy choice.

Still another factor that has recently dictated the choice of rare earth alloys in preference to the Mg-Al-Zn family alloys is the superior thermal conductivity of the former. In certain instrument housings where heat transfer has been a consideration, EZ33A alloy has been designated primarily on the basis of this characteristic. In addition, this alloy has a high damping capacity, which further enhances its use in applications where vibration suppression is necessary.

No news, either, is the fact that the development of the thorium-containing alloys, such as HK31, represented a further advance in designing for elevated temperature applications. As a testimony to the fact that the thorium alloys are no mere laboratory curiosity, and in spite of the costly nature of the alloying ingredients, the author's company's foundry alone has produced over 750,000 lb of thorium-containing alloy castings to date.

There has been much less commercial exploitation of the high strength, room temperature, magnesium alloys that have been made available. The Hg-Zn-Zr alloys, such as ZK51 and ZK61, offer outstandingly high room temperature properties, but are considerably less castable than the conventional Mg-Al-Zn family alloys, especially in thin wall configurations. It is also most difficult to weld repair the Mg-Zn-Zr alloys successfully. Various additions such as rare earth and thorium to the Mg-Zn-Zr alloys have been developed to overcome these weldability and castability shortcomings. It is believed that all of these alloys have excellent potential, and that there will be increasing exploitation of them in this country as there has been in England and in Canada.

A rather recent development is the composition QE22 alloy, a silver-didymium-zirconium alloy, developed in England, where it is designated as MSR alloy. It can be reported that this alloy has castability comparable to Mg-Th-Zr alloys. It has the advantage of possessing not only excellent room temperature properties, but that it retains good strength into fairly high temperature ranges. It is sensitive to the rate of cooling after solution heat treatment, and therefore, requires a rapid quench. This along with the costly nature of its constituent alloying elements constitute its most serious deficiency.

The ability of didymium to increase the strength of magnesium at elevated temperatures has also been exploited in EK31XA alloy, where didymium has been used to replace the mischmetal, and thereby, increase the properties of an established alloy.

QUALITY CONTROL IMPROVEMENTS

A few words might also be said about the improvements in quality control techniques. The inspectors are continually finding more and better ways to find defects. This is discouraging to production people, but has the effect of opening design frontiers where every part must have the ultimate that the alloy can deliver.

Freezing a small sample of metal under vacuum is commonplace in the aluminum casting industry as a method for checking for dissolved hydrogen. By lowering the solidification pressure, this technique is applicable to the Mg-Al-Zn alloys, allowing magnesium founders to check and control the amount of dissolved hydrogen before pouring.

In the field of x-ray nearly all of the magnesium foundries have changed to a finer grained, relatively slow film in the last few years. This change tends to insure high contrast, which gives defects better definition.

Ultrasonic inspection of castings has, in general, been unsatisfactory because the equipment could not differentiate between defects and the naturally occurring changes in section. Ultrasonic equipment is now available, however, that will read wall thicknesses. This is important in applications where long small cross-section passageways are cast in, and until this equipment became available, only destructive testing could tell the wall thickness of devious passageways in a casting.

Improvements have also been made in the dye penetrant inspection field. Not only have more effective systems been made available for complete all-over inspections, but dye penetrants and developers are now available in small pressure bottles for checking small areas. This latter system lends itself well to the first inspection operation, to make quick inspections on doubtful sections of castings.

SUMMARY

Recent developments in magnesium foundry practice have allowed the industry to encompass more designs by offering larger castings, more dimensionally precise castings, castings with more intricate coring, castings with relatively extensive thin walls, casting with more versatile physical properties and castings of even more consistent high quality. While most of these developments are only extensions of older technology, the sum of them is impressive.

FABRICATION METHODS EVALUATION

by J. G. Frantzreb

ABSTRACT

Through modern technology new materials and processes have been formulated. To use these new processes efficiently, one must evaluate each process and utilize the one most applicable to sound manufacturing and economics. Castings, forgings, shaping and joining processes are evaluated by the author. If the engineering designs and applications for a given part are exacting, and the materials and processes used which are best suited for the particular part, economic operation can be realized.

INTRODUCTION

"Economic methods and material application" is a doctrine in business operations that is as basic and vital as livelihood itself. It is so fundamental that it has been the motivating force around which business life exists and thrives. It is natural then that it be woven into all the functional aspects of industry. Its industry-wide appeal and importance is attested to by the millions of dollars which are being spent on research and manufacturing development. It has generated, more than anything else, a systematic approach to all manufacturing problems and has tied together all levels of manufacturing to this cause.

To start such a program you will find inertia on the part of many to impede your way. Figure 1 shows an appropriate list of idea killers.

At the author's company we operate under a philosophy of *"I.T.A.B.W.O.D.I."*-or-"Is there a better way of doing it?" In looking for better ways to make a given part we naturally turn to those that are currently in production which can be made by a better method. The conditions that predict how a given part will be fabricated are always changing. The quantity of parts to be made changes as production continues; in addition, the quality level may change with field experience.

Economics Effect

Often times these better ways are not the new and exotic type, but are straight forward and purely economic decisions. Figure 2 shows a bracket which was initially fabricated, and was a satisfactory and economical part at the time. As production increased, there was sufficient justification cost-wise to make it as a casting. The result was a more economical, better and cheaper part.

Figure 3 shows another bracket which was changed from a welded fabrication to a simple formed plate.

There are innumerable more examples of changing from one fabrication method to another. This is a never ending process. To continue a little further, a piece of tubing and barstock welded together was converted to a simple forging. This conversion resulted in a considerable savings. Another part was

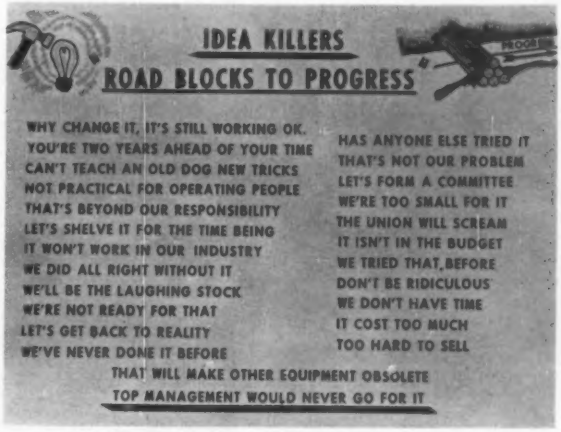
IDEA KILLERS
ROAD BLOCKS TO PROGRESS
WHY CHANGE IT, IT'S STILL WORKING OK.
YOU'RE TWO YEARS AHEAD OF YOUR TIME
CAN'T TEACH AN OLD DOG NEW TRICKS
NOT PRACTICAL FOR OPERATING PEOPLE
THAT'S BEYOND OUR RESPONSIBILITY
LET'S SHELVE IT FOR THE TIME BEING
IT WON'T WORK IN OUR INDUSTRY
WE DID ALL RIGHT WITHOUT IT
WE'LL BE THE LAUGHING STOCK
WE'RE NOT READY FOR THAT
LET'S GET BACK TO REALITY
WE'VE NEVER DONE IT BEFORE
HAS ANYONE ELSE TRIED IT
THAT'S NOT OUR PROBLEM
LET'S FORM A COMMITTEE
WE'RE TOO SMALL FOR IT
THE UNION WILL SCREAM
IT ISN'T IN THE BUDGET
WE TRIED THAT, BEFORE
DON'T BE RIDICULOUS
WE DON'T HAVE TIME
IT COST TOO MUCH
TOO HARD TO SELL
THAT WILL MAKE OTHER EQUIPMENT OBSOLETE
TOP MANAGEMENT WOULD NEVER GO FOR IT

Fig. 1 — To overcome the inertia in beginning a program of systematic approach to all manufacturing problems, many "idea killers" or "road blocks to progress" must be overcome.

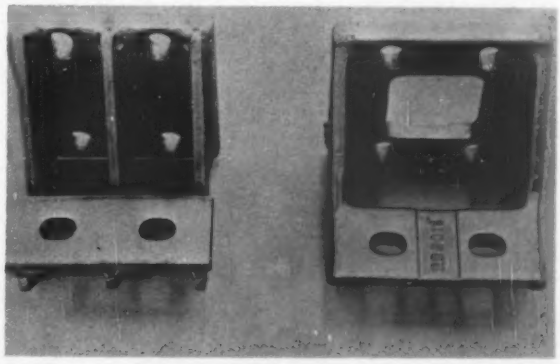

Fig. 2 — Left — bracket which was fabricated in old method of manufacture. Right — new method of manufacture shows bracket as a casting.

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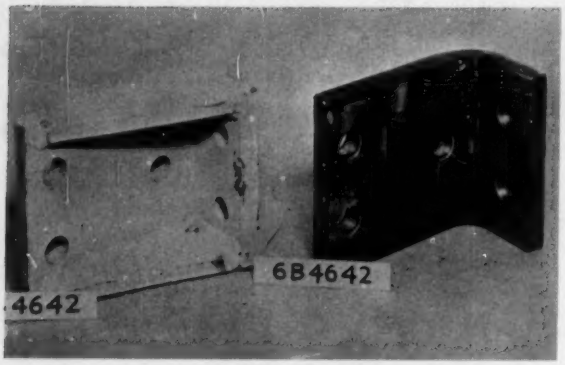

Fig. 3 — Bracket which was changed from a welded fabrication (left) to a formed plate (right).

made from a forging and is now being made from barstock at a considerable savings. The conversion does not always go in the same direction. Some parts are converted to castings, as some are converted to other processes.

New Technology

Many times changes are associated with new technology. One part that was a gray iron casting was converted to a high strength aluminum die casting. This conversion created a part of equal or superior strength at a lesser cost and also a part with greater customer appeal, as far as appearance is concerned. Figure 4 shows a bracket on which used to be arc welded a small nut. Projection welding made a more presentable part at a lower cost.

Figure 5 shows a riveted assembly on the left which was converted to a weldment. This change produced a stronger and cheaper part. It is interesting to note that the weldment on the right has been further refined. Sometimes these conversions are more simple than this. Figure 6 shows a slotted nut which, by changing the casting method, is now cast in the slot eliminating a machining operation and saving several thousand dollars a year. Sometimes a change in materials can save money. Figure 7 shows a bronze casting that was changed to an aluminum casting. Figure 8 shows an example that went in the other direction, that is, from an aluminum part to a gray iron part.

These figures (Figs. 1-8) show that each part must be studied individually, and the best and most economical method of fabrication must be chosen when one considers the production requirements, the strength levels and the other factors which predict the fabrication procedure that will be used. In any type of production business, designers must be constantly looking at these factors if they are going to remain an economical producer. Our competition

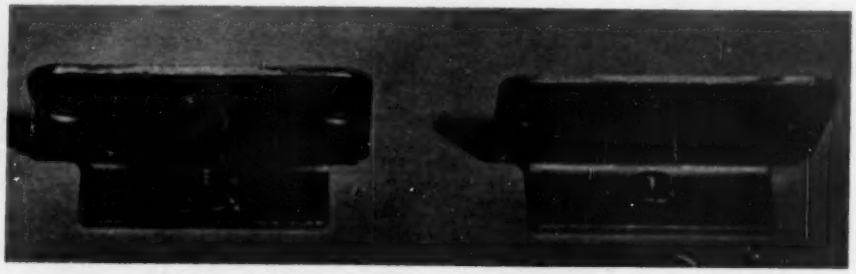

Fig. 4 — Bracket which was changed from arc welding (left) to projection welding (right).

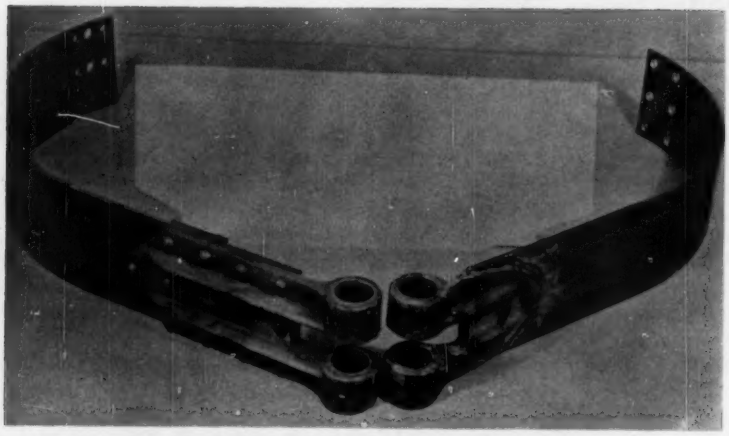

Fig. 5 — Riveted assembly (left) which was converted to a weldment (right).

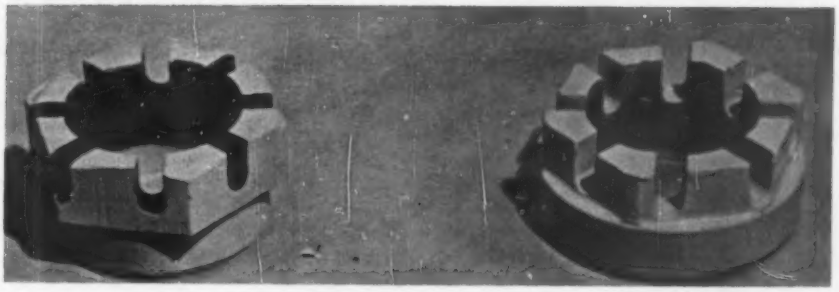

Fig. 6 — Slotted nut which by changing casting method is now made with cast in slots and machining is eliminated. Left — milled slots; right — cast slots.

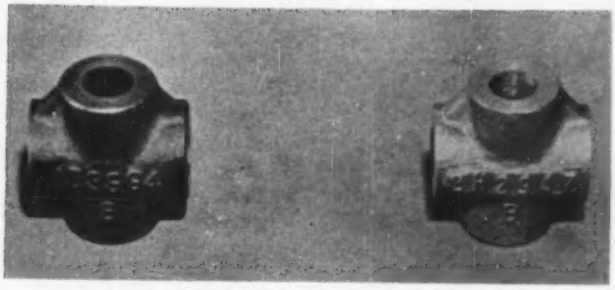

Fig. 7 — Casting that was converted from bronze (left) to aluminum (right).

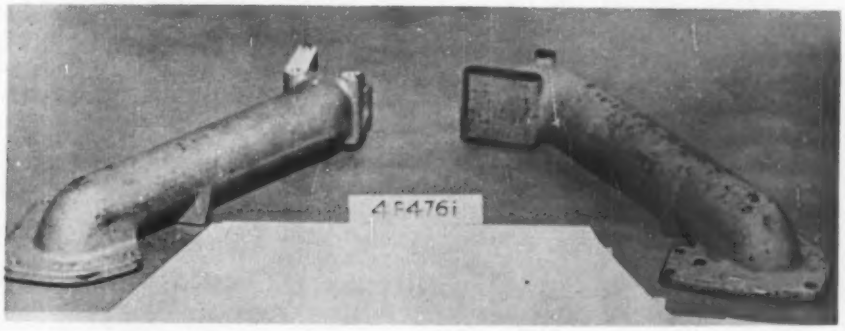

Fig. 8 — Casting that was converted from aluminum (left) to gray iron (right).

will not let us forget the lessons that can be shown in these figures.

Material Economic Use

The economic use of material, then, is dependent in great measure upon economic methods of fabrication which, in turn, embraces many aspects of processing. The goal is to keep the manufacturing cost per piece to a minimum, and to this end we must channel all our manufacturing, metallurgical and purchasing skills to make it a reality.

This economic use of materials and methods should be of deep concern to the foundry industry for it affects the industry's existence. Table 1 showing foundry tonnage as reported by the bureau of census for years since World War II seems to point this out. While other manufacturing industry has had a reported annual growth of 3 per cent per year, the foundry industry has not shared in this growth, so by comparison has lost ground. These materials are all being replaced by design changes to some alternate.

TABLE 1 — INDUSTRY TRENDS

Type	Annual Tonnage Loss
Gray Iron Castings, %	3
Malleable Iron Castings, %	3
Steel Castings	0
Non-Ferrous Castings, %	5
Steel Forgings, %	7

FOUNDING

If a person were to spend some time in observing modern road construction or mining operations, he would be impressed by the ruggedness of the earth-moving equipment employed. Upon further observation he would see a veritable steel monster made up of intricate combinations of sturdy metal assemblies being subjected to almost unbelievably high loads. At the author's company the important part

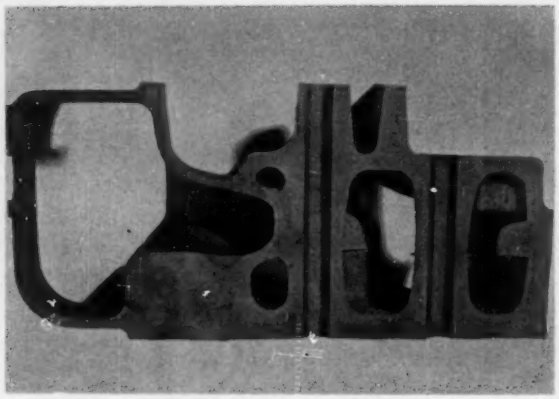

Fig. 9 — Section cut from a cylinder head.

iron and steel play in the ultimate performance of the product is realized. It must be sound, and it must lend itself to correct fabrication and processing. For this reason, the company's interest extends to the pouring ladle itself.

There are three inherent basic problems in foundry practice which have caused stumbling blocks in subsequent fabrication operations, and which have resulted in costly changes in processing or initiated added expense in the form of closer controls.

Cleanliness

Cleanliness of cast products presents annoying problems when machining is required. Valuable tools are broken and time is lost. Cast surfaces that are painted soon point up to the ultimate customer the quality of the product he has received. Today's increased use of complicated hydraulic castings demand the ultimate in cleanliness to protect delicate mechanisms.

It is hoped that the day is not too far when castings are available with minimum concern for their cleanliness status.

Tolerance

An intimate understanding of the planned processing a customer intends to use is a must for successful foundry products. Locating points from which dimensions are controlled must be free of parting lines, draft and other variables.

Soundness

Due to the pressure in releasing casting drawings, and the lack of adequate lead time, foundries are some times forced into making quality subordinate to economy and urgency. The practice of panoramic x-ray examination, and then sectioning the initial casting or castings following pattern change, is to be highly recommended as a means of shortening the time required to produce castings with superior reliability.

MATERIALS

It is beyond the scope of this presentation except to hint at the tremendous activities taking place in the development of materials. Problems of strength, fatigue and notch sensitivity, weight, heat and corrosion resistance, extreme wear and higher horsepower all have challenged the engineer in exploiting the full potentials of materials (Table 2).

TABLE 2 — COMPARATIVE PHYSICAL PROPERTIES

	Tensile Properties, psi	Elong., %	Endurance Limit, psi
Cast Materials			
Gray Iron			
	30,000	0	14,500
	40,000	0	19,000
Pearlitic Malleable	60,000 yield; 80,000 ult.	3.0	32,000
Pearlitic Ductile	60,000 yield; 80,000 ult.	3.00	32,000
Cast Steel	45,000 yield; 80,000 ult.	17.00	38,000
Wrought Steel			
Mild Steel	43,000 yield; 65,000 ult.	36	33,000
Hi Mn-Lo Carbon	45,000 yield; 70,000 ult.	22	35,000

It has expanded and it is continuing to extend the potentials of ferrous and nonferrous metals. High strength alloys with strength levels approaching 400,000 psi are in sight. Magnesium and aluminum offer great possibilities for light metals with relatively high strengths. Powdered metals are being pressed into shape, and are being used as bearing materials to replace copper-base metals.

The alloying effects of elements such as rare earths, columbium, vanadium and the old standbys, sulfur and lead are continually being evaluated to enhance the fabrication and utilization of metals at higher hardness and strength levels.

The usage of plastics is extending beyond the household commodity. They are becoming more and more a part of the author's company's prime products in applications previously made of metal or other materials. Reinforcement of plastic parts can be done through overlay or coated type construction, as well as metal particle impregnation to enhance the toughening properties of plastics for applications where more strength is required.

It is important to note that materials (irons included) are being purchased more and more with specific metallurgical properties of specific physical requirments, and are being combined in farbricized designs to take advantage of the full potential of each material in a composite assembly. Needless to say, the burden of application lies in establishing sound and practical manufacturing methods to adopt such designing principles.

CASTINGS

The casting technique is the most direct in converting molten metal in a specifically prepared mold into a desired shape. Figure 9 is a section cut from a cylinder head.

Strength requirement is a factor in the use of castings. However, even within their strength potential they must compete with other methods of fabrication on a cost/piece rather than cost/lb basis (Fig. 10). For example, you will note, in comparing the casting with its fabricated counter part, that the cost/lb is practically the same. Because of the added weight of the casting necessary to perform the same function as the fabricated assembly, the cost of the

casting is approximately one-third more. In this particular case, the fabricated assembly affords better overall performance because of some design advantages built around better material properties, that is to say, the ability to put the right material in the right place.

In offering higher strength and tougher material, the casting industry is looking to malleable and ductile iron and steel castings. Table 2 shows relative strength levels of these type castings as they compare with gray iron and wrought steel. It should suffice to say that adding alloying elements and special heat treatment can elevate these physical properties. One must assure himself that he has the necessary metallurgical quality in these materials to guarantee the physical properties published for each material.

To improve the weight factor and finish the castings, better control and special techniques are much in use today. Notable among these is shell molding, made of fine grain sand and a resin binder in a highly finished pattern which is cured by heating to further harden and strengthen the mold. Where warranted, it is better than green sand molding, and in many cases the resultant casting tolerances have been close enough to eliminate some machining costs—drilling operations included. Large and fast molding equipment is a must in economic casting operations. One such method is the blowing of a shell mold, schematically shown in Fig. 11.

Closely related in significance is carbon dioxide (CO_2) molding. This molding technique uses green sand mixed with a water glass binder, and is set by gassing the mold with carbon dioxide. The mold is hard and rigid, and maintains close tolerances and surface finishes similar to shell molding. This method lends itself well to small lots and requires a minimum of equipment.

Another is permanent molding. As the name suggests the mold can be reused and can be made of graphite, gray iron, water-cooled copper molds, to name a few. This application is predominately for nonferrous cast material. Because of the rigidity of the mold close tolerance can be maintained.

In pressure casting the molten metal is forced into a mold cavity by centrifugal force or ram pressure. Sounder and denser castings are obtained with this method. In obtaining closer control on melting practice, induction and vacuum melting is also in use.

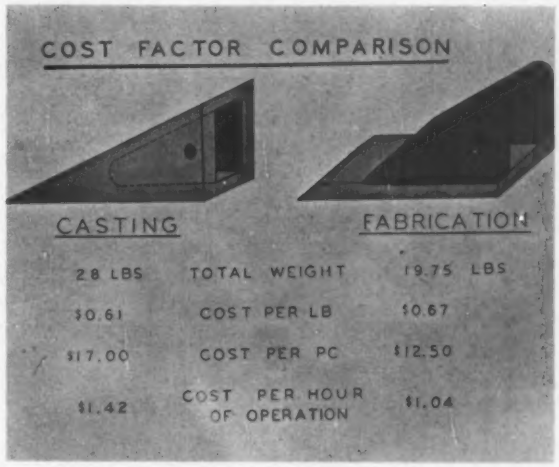

Fig. 10 — Cost comparison between casting and fabrication.

FORGING

Forgings like castings find themselves in the same cost competition, though not restricted to the same strength limitations. Hammer, drop and upset forging capacities have expanded to include presses of 50,000 tons, open frame press 200 tons and closed die forgings weighing 5 tons. Automatic mult handling and induction heating have reduced the cost of the unit forging. In the case of induction heating, heat can be applied to only that portion of the mult that needs to be formed. High die costs tend to keep forging costs up.

Ingot improvement, standardization of billet sizes for forging mults and closer dimensional forge tolerances are all keys to forging progress.

Cold extrusion techniques go a long way in solving some of the dimensional problems of conventional forging and are economically attractive especially where less initial material can be used and high production is required. Figure 12 shows a slug of metal being cold extruded forward and in reverse

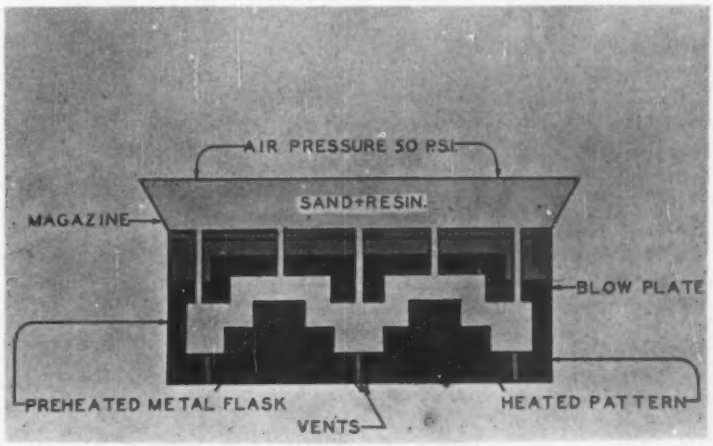

Fig. 11 — Shell molding blower.

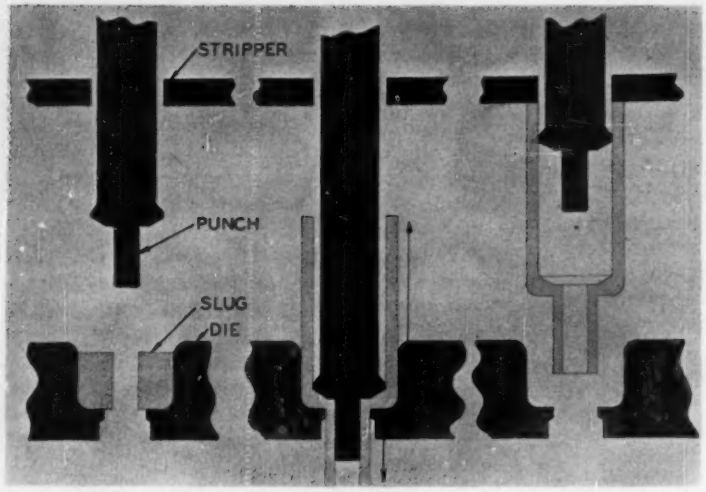

Fig. 12 — Cold extrusion.

simultaneously with the nose of the punch, guiding the smaller section of the extrusion through the die while the larger diameter section flows back over the punch guided by the top portion of the die. Practically all of the original slug is used to give an extruded part with close enough tolerances so as to require little or no machining, depending on the application.

Cold extrusion lends itself well to cylindrical shapes. Size applications are limited to approximately 25 lb extrusions. Further limitations are caused by available lubricants needed to condition the surface during deformation. The operation is rapid and the cost of operation somewhat expensive. Therefore, heavy production is needed to offset this cost so that the cost per piece can be low enough to make this application desirable.

Forming

There are several new advances in metal forming. One is mechanical which uses intricate machinery to bend plates in multi-directions (Fig. 13). Localized heating of the affected areas as well as metal stretching can be incorporated. The economy of this operation is such that a fabricated assembly can be produced with a minimum amount of joints. This could mean a reduction in welding or fastening operation.

The use of explosives is the more exciting innovation in forming (Fig. 14). The work piece or blank of metal is placed over a female die. An explosive charge of a prescribed amount is placed over the blank at a measured distance. Upon detonation, the impact forces the blank into the die cavity making it conform to the shape of the die. The illustration shows the charge in a liquid medium which adds to the flow and direction of the charge impulses.

In addition, the die can be subjected to a vacuum to accelerate, even further, the almost instantaneous forming action. Parts of varying shapes and sizes can be formed, and one would do well to seek out the benefits of this method of forming on parts that are difficult to form otherwise. Some companies are now realizing a cost savings with the use of explosive forming.

Spin forming uses spinners or rolls to shape a sheet or a blank of metal to the contour of the rolls. Figure 15 shows a sheet of metal being spun into a cone shape. The cost figures shown in this figure establish the trend of application. Note the high tool cost for stamping. High production would tend to offset this. Note, too, that automatic spinning tends to reduce further the cost of forming. However, amortization costs tend to increase it. Needless to say, high production is the key to lowering any unit cost. Incidentally, hot spin forming is also employed in shaping more simplified blanks which prior to this were formed in forging presses.

SHAPING

Flame Cutting is fast taking its place along side shearing operations. In fact, flame cutting equipment offers a low initial investment cost, and lends itself to cutting heavier plates, more intricate shapes and in the case of thin sheets or plates stack cutting can be done. The multi-burner layouts are electronically controlled to give fine cuts, and with the use of less expensive fuel such as natural gas flame cutting costs can be equal to and even less than shearing. (Fig. 16)

In the case of intricate shapes, with the use of proper flame cutting procedures distortion can be held to a minimum. Multi-shearing and punching operations can be consolidated into one cutting operation and expensive dies can be eliminated. This can be a significant factor in cost of operations, particularly where the cost of expensive dies must be absorbed in small production lots.

Stamping and blanking is a rapid method of shaping materials, because it lends itself to mechanical handling of material offering an extremely economical operation. Stack stamping as is the case with stack flame cutting is also effectively used.

MACHINING

The trend in modern machine application is to combine as many operations as is possible in one machine. Where several operations were performed on different machines and stations, today we have ma-

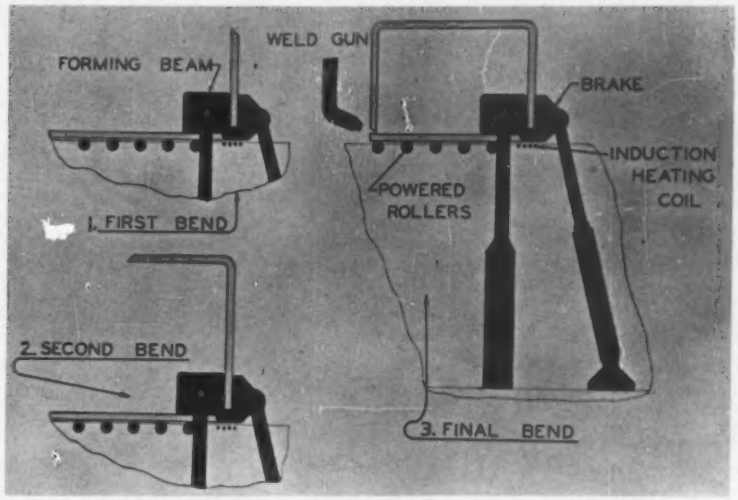

Fig. 13 — One piece construction in multi-directional bending.

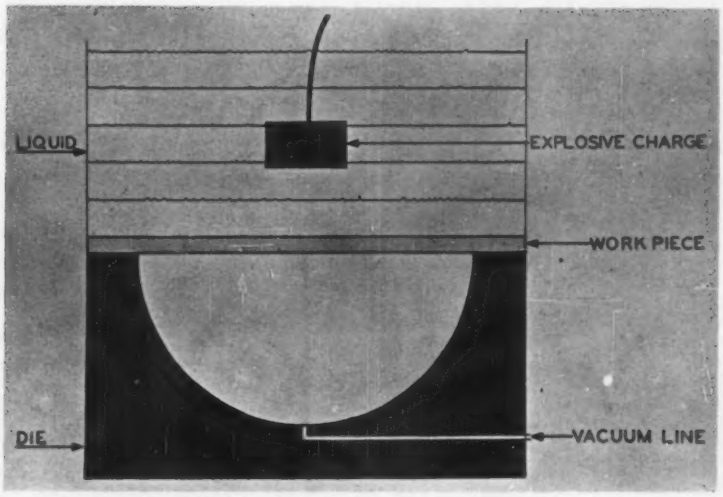

Fig. 14 — Explosive forming with explosive charge in a liquid medium which adds to the flow and direction of the charge impulses.

CONES	100	500	1000	5000	10,000	TOOLS
STAMPING	$2.60	1.80	1.60	1.60	1.60	$12,000.00
SPINNING	$3.74	3.56	3.53	3.50	3.48	$175.00
AUTOMATIC SPINNING	$1.80	1.38	1.32	1.26	1.24	$1500.00
		WITH TOOLS AMORTIZED				
STAMPING	$122.60	25.80	13.60	4.00	2.80	
SPINNING	$ 5.50	3.91	3.71	3.53	3.49	
AUTOMATIC SPINNING	$16.80	4.38	2.82	1.56	1.39	

Fig. 15 — Spin forming.

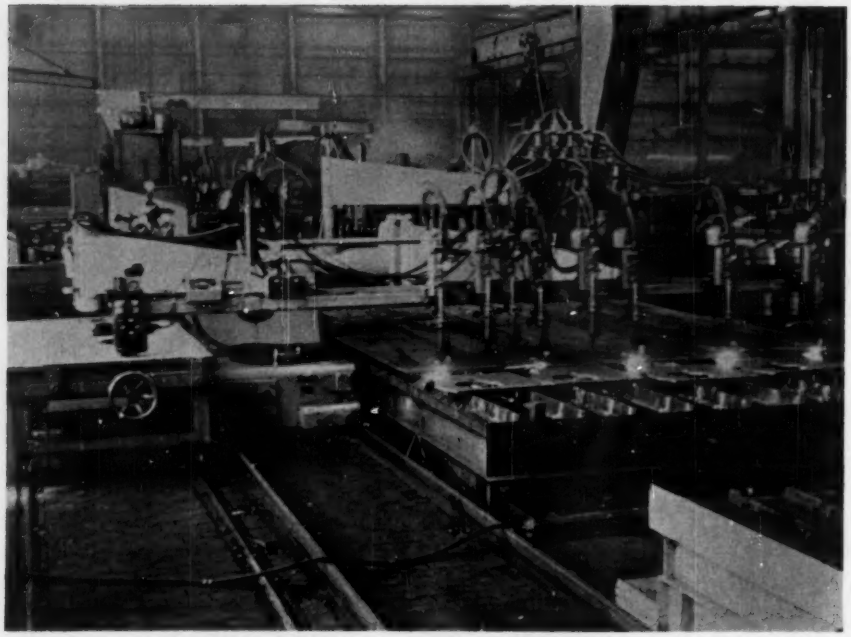

Fig. 16 — Flame cutting.

chines that do multiple operations with one setup. Indexing and machine cycle manipulation of speeds and feeds are automatically being adapted for numerical or program control. Tape controls previously prepared by computer or hand computations are applied. The results are measured in uninterrupted production, and overall higher efficiency. Production lines can be laid out to complete the mechanization of individual machines and operations.

JOINING

In the past 10 or 15 years, welding has made tremendous strides. It is not treated as an art any longer, but as a science. Weld application has received most of its stimulation from a resulting trend toward fabricated assemblies. The designer is continually seeking to combine best materials in the most simplified construction so as to make an assembly as adaptable, light and strong as is possible. Welding has been an important tool in fulfilling the designer's wishes in an efficient manner.

Recognizing the fact that welding is an established science, it has definite restrictions in application. Throughout its use, we seek to apply the best know-how and precautions to give a metallurgically sound weldment that will first meet engineering requirements and one that will give a good appearance. To do this, many methods of welding are available. Knowing first which techniques are applicable select the one which is most economical.

In considering the economic weld operations, certain factors should be kept in mind.

1) Simplicity of operation—whether it is adaptable to automatic or fixture type welding to gain more actual welding time.
2) Adaptability to automatic positioning.
3) Fastest rate of weld metal deposition.
4) Least effect on parent metal.
5) Alignment of the assembly.

There are many basic and also exciting weld techniques available, each with its own potentials.

Stick electrodes (Fig. 17), in spite of all the new innovations will continue to be used in good measure. They are utilized in inaccessible areas and for complex constructions. Iron powder electrodes make use of a bare rod covered with a heavy iron powder coating which when subjected to higher current loads will melt and deposit as much as 100 per cent more weld metal than a conventionally coated electrode.

Continuous Wire Welding

Continuous wire electrode welding can be substituted for the stick electrode when better accessibility to the weld joint and more continuous welding is possible. The wire serves as the electrode which is fed and consumed in a molten pool. The rate of wire feed is usually controlled by load or voltage variations. There is a definite correlation with the wire size, speed, voltage, current and gap as it relates to a certain joint. Greater depths of penetration and deposition rates are obtainable.

One such system uses a powder flux which flows down and around the wire and helps shield the molten pool. This system is known as submerged arc welding. Another system uses gas such as argon or carbon dioxide in place of the flux powder used in submerged arc welding. It is usually referred to as inert gas and CO_2 welding. These systems can be used in combination, and do give clean welds. In most cases, cleaning operations are reduced appreciably and even eliminated.

For rapid weld deposition and deep penetration the electroslag method (Fig. 18) can deposit as much as 45 lb of metal/hr as compared to the more conventional continuous wire welding of 22 lb/hr. The electroslag can utilize multi-wire welding and a three

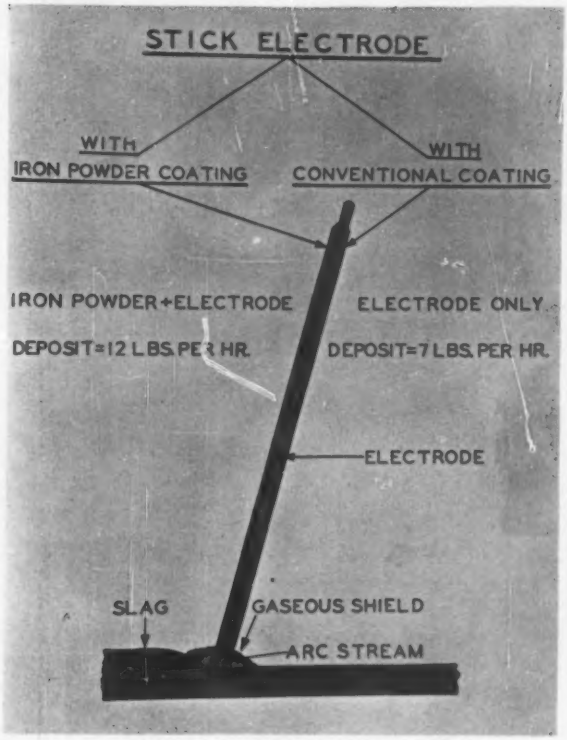

Fig. 17 — Stick electrode welding.

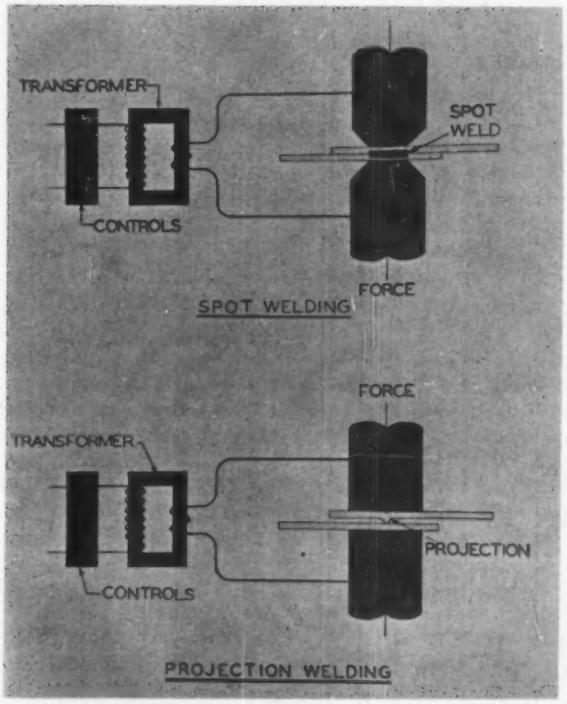

Fig. 19 — Resistance welding.

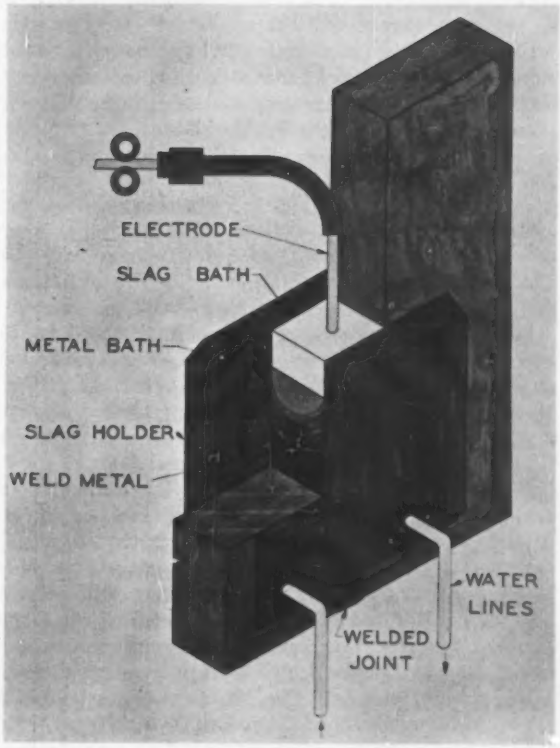

Fig. 18 — Electroslag welding.

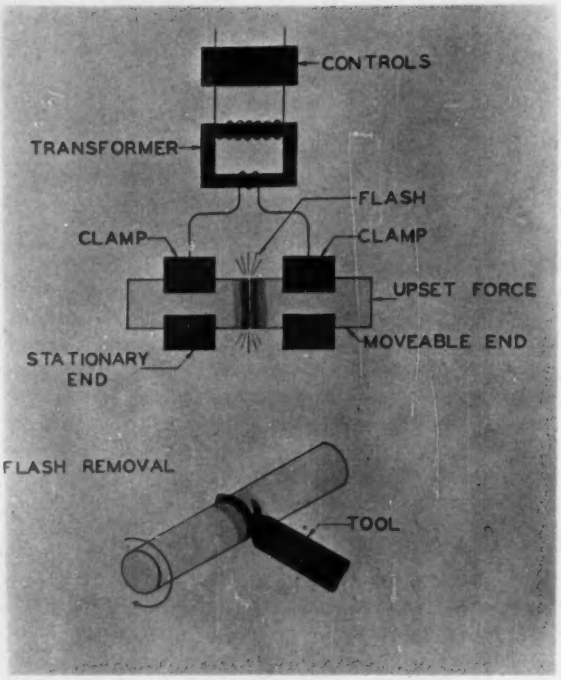

Fig. 20 — Flash welding.

wire setup can deposit as much as 135 lb/hr. No grooves or joint preparation is necessary to weld a 6 in. thick plate throughout in one pass. A flux cored wire is used.

You will note, too, that the electrode contact is much further back on the wire so as to place more of it in the resistance field. This gives the effect of preheating the consumable electrode, and boosts its melt down rate. The pool of slag above the molten metal deposit adds to the resistance of the cycle, and too it increases the heating rate of the wire.

Resistance Welding

Resistance welding (Fig. 19) joins two metal sections by placing these sections between copper electrodes. Current is conducted from one electrode to the other through the metal. The electrical resistance of the metal produces sufficient heat to fuse the metal under an applied pressure. Interrupted welds can be employed so as to reduce the cost of more extensive welding. To facilitate spot welding, projections are preformed on surfaces to be welded so that the current and heat can be concentrated more effectively.

There are several modifications to resistance welding. In flash welding (Fig. 20) the current jumps across a controlled gap between two metal faces, and the metal faces are heated in this fashion until they become plastic. At this point the metal is pressed together and fused. Flash weld is usually employed for butt welding. The weld action is rapid, and there is but a narrow heat affected zone in the parent metal adjacent to the weld. The flash or excess metal is removed after welding. Dissimilar metals can be joined more effectively in overcoming the problem of difference in thermal expansion.

Wherever possible automatic or semi-automatic welding is used. It supplies a more efficient operation, higher quality and better reproducible welds. A good example of progressive continuous welding can be found in the welding of tube stock. As the sheet of plate is progressively wrapped around in a tubular form, the butt faces make point contact with electrodes that heat these faces to a plastic heat. Pressure is then applied to the heated faces which fuses them together.

Positioning fixtures are important in welding. Weld processing of a complex structure must be well procedured to reduce distortion or movement. Proper fixturing will allow the grouping of various weld sequences in the most efficient manner.

There are several welding techniques which include the most advanced scientific methods. These are electron beam, plasma heat and ultrasonic welding.

Brazing

High temperature brazing is much in evidence particularly in the application of honeycomb or sandwich constructions. Sheets are sandwiched together by a ribbed or corrugated center and placed in a high temperature furnace, which is atmosphere controlled to keep the assembly clean. Copper is generally used in fusing the multi-joining faces.

The aircraft industry has stimulated the use of adhesives in metal joining. This was brought about by the use of resin in combination with rubber which when cured gives a high strength due to the thermal setting of the resin and the vibration resistance supplied by the rubber. Aluminum and plastic honeycomb or sandwich constructions which have been joined by adhesives are used in aircraft fabrication to take advantage of greater strength to ratio structures. Adhesive mixtures are critical in nature and need close control. Many types of quality control tests are employed to maintain functional quality of the joints produced.

CONCLUSION

Modern technology has formulated a steady procession of new and exciting materials. Just as exciting is the parade of unique processes accompanying them. In their use, one can greatly affect the other; so they must be placed in the right perspective. We cannot speak of economic use of materials unless we give due consideration to the methods that are available to utilize them.

As necessary as economic operation is to sound manufacturing operation, it is not obtained just for the asking. Rather, it is earned by exacting engineering designs and application, blended with the proper use of the best materials and manufacturing processes available, supported by a well rounded complement of trained personnel who can produce the intended end product and submit it to the customer at a price he can afford and is willing to pay.

Economic operation is a day-in and day-out conscientious effort of systematically going about doing a good job of measuring and recognizing all the factors that go into making a job more efficient and putting them to proper use.

BASIC-ELECTRIC STEELS DEPHOSPHORIZATION AND DESULFURIZATION KINETICS

Some considerations

by J. Zotos and E. DeLuca

ABSTRACT

Data generated in recent metallurgical process investigations were analyzed to study the kinetics of dephosphorization and desulfurization during the production of steel in a 6½ ton basic-electric arc furnace. The analysis revealed:

1) Dephosphorization proceeds in accordance with the transfer reaction

$$P_{metal} \rightarrow P_{slag} \qquad (12)$$

and is representative of a first-order type kinetic reaction with respect to the steel's phosphorus content. The logarithmic rate of dephosphorization $\left[\frac{d \log [P]}{dt}\right]$ is constant throughout the oxidizing period of a heat, but increases in magnitude from heat to heat when the average dephosphorizing power $\left[\frac{(P)}{[P]}\right]$ increases in value.

2) Desulfurization proceeds in accordance with the transfer reaction;

$$S_{metal} \rightarrow S_{slag} \qquad (23)$$

and is representative of a first-order type kinetic reaction with respect to the steel's sulfur content. The logarithmic rate of desulfurization $\left[\frac{d \log [S]}{dt}\right]$ is constant throughout the reducing period of a heat, but increases in magnitude from heat to heat when, a) the average desulfurizing power $\left[\frac{(S)}{[S]}\right]$ increases in value, or b) an average slag parameter equal to the slag's basicity divided by its oxidizing power $\left[\frac{(\%\ CaO)}{(\%\ SiO_2)\,(\%\ FeO)}\right]$ increases in magnitude.

INTRODUCTION

A complete description of the chemistry of steelmaking must necessarily include the kinetics of the refining processes. The term kinetics must be interpreted in the broadest sense to include, in the case of a heterogeneous reaction, rates of mass transfer to and from a phase boundary and rates of simultaneously occurring reactions at the phase interface. A metal-slag reaction is, therefore, generally described as involving transfer of the reactants from the bulk phases to the metal-slag phase boundary, single or multiple reactions at the boundary and transfer of the reaction products from the boundary into the bulk phases.

Limiting cases whereby the overall process rate is controlled by the rate of sufficiently slow step are, fortunately, of frequent occurrence and permit attention to be focused on either a single mass transfer step or a single boundary reaction.

Desulfurization kinetics of carbon-saturated iron and steels in the molten state has been the topic of a number of laboratory and plant-scale investigations.[1,2,3] While laboratory investigations are fruitful in testing hypotheses and/or evolving mechanisms, there is no great certainty in extrapolation of the quantitative results to plant-scale facilities. This unfortunate consequence follows from the inability to separate the quantitative results of kinetic experiments on heterogeneous reactions from the geometry and convection patterns associated with the reaction vessel.

Hence, analysis of production-scale data in light of existing theories and mechanisms would seem to be of value in establishing actual production-scale quantitative results. This report is the result of such an analysis.

The kinetic theory of the general metal-slag reaction has been presented in the literature.[4] A common assumption in the analysis of a metal-slag refining process is transport control. The assumption of transport control here, or, equivalently, postulation of chemical equilibrium at the metal-slag phase boundary, is in keeping with the electrochemical nature or "nonmolecularity" of the pertinent phase boundary reactions.

If it is further assumed that the overall rate of the refining process involving removal of species i from the metal phase is controlled by transport of the species from the bulk metal to the phase boundary, then for a differential element of interface area, the instantaneous rate of mass flux or species i from the metal to the slag may be written as

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$$F_i = \frac{D_i}{\delta_i}(C_i^B - C_i^I) \qquad (1)$$

where

D_i is the diffusion coefficient in the metal.
δ_i is the effective boundary layer thickness.
C_i^B is the bulk metal molar concentration.
C_i^I is the interface molar concentration.
i denotes species *i*.

This assumption is justified on the basis of a highly turbulent slag. Neglecting variations in the term $\frac{D_i}{\delta_i}(C_i^B - C_i^I)$ with position on the interface surface, the total instantaneous mass flux is then given by

$$\int_A F_i dA = \frac{D_i A}{\delta_i}(C_i^B - C_i^I) \qquad (2)$$

where integration is over the area *A* of the metal-slag phase boundary.

From a material balance on species *i*,

$$-\frac{D_i A}{\delta_i}(C_i^B - C_i^I) = \frac{d(VC_i^B)}{dt} = V\frac{dC_i^B}{dt} \qquad (3)$$

or

$$-\frac{dC_i^B}{dt} = \frac{D_i A}{\delta_i V}(C_i^B - C_i^I) \qquad (4)$$

where *t* denotes time, and *V* the volume of the metal, is taken as constant. If it is assumed that C_i^I is small in comparison with C_i^B, and that variations in $\frac{D_i A}{\delta_i V}$ are negligible, then

$$-\frac{dC_i^B}{dt} = a_i C_i^B \qquad (5)$$

where

$$a_i \equiv \frac{D_i A}{\delta_i V} \qquad (6)$$

and is constant.

By definition,

$$C_i^B = \frac{N_i}{V} = \frac{W_i}{V(MW)_i} = \frac{Y_i \Sigma W_i}{V(MW)_i} = \frac{Z_i \Sigma W_i}{100\,V(MW)_i} \qquad (7)$$

where

N_i denotes moles.
W_i mass.
$(MW)_i$ molecular weight.
Y_i mass fraction.
Z_i mass per cent.

As a close approximation, we have

$$\frac{dC_i^B}{dt} = \frac{\Sigma W_i}{100\,V(MW)_i}\frac{dZ_i}{dt} \qquad (8)$$

and equation (5) may be written as

$$-\frac{dZ_i}{dt} = a_i Z_i \qquad (9)$$

from which

$$-\log_{10} Z_i = \frac{a_i}{2.303}t + b_i \qquad (10)$$

With the given assumptions, the transfer reaction written schematically as

$$i_{metal} \rightarrow i_{slag} \qquad (11)$$

may be said to be of "first-order" with respect to species *i*.

PROCEDURE

Data obtained in recent metallurgical process investigations at the Rodman Laboratory of Watertown Arsenal were analyzed using equation (10) in order to study the significance of the proposed pseudo-first-order kinetic model for desulfurization and dephosphorization under actual basic-electric steelmaking conditions. The process investigations were conducted for the purpose of developing an operating procedure for producing high quality, low sulfur and low phosphorus steels in a 6½ ton, basic-electric arc furnace.

The melting practice, previously reported in detail,[5] initially produced 4140 A.I.S.I. steel and was later used to produce 4330, high nickel 4325, 1040 and 4340 A.I.S.I. steels. At periodic time intervals during the desulfurization, or reducing, period and dephosphorization, or oxidizing, period, samples of metal and slag were extracted from the respective bulk phases. The steel samples were quantitatively analyzed for elemental content (sulfur and phosphorus included) and the slag samples for silicon dioxide, iron oxide, calcium oxide, sulfur and phosphorus content.

RESULTS AND DISCUSSION

Dephosphorization occurs only during the oxidizing period of a basic-electric heat. Taking the ith component as the element phosphorus during this stage of the refining cycle, equation (11) can be written as

$$P_{metal} \rightarrow P_{slag} \qquad (12)$$

Denote *[P]* as the weight per cent of phosphorus in the liquid metal and (P) as the weight per cent of phosphorus in the slag. Thus, equation (10) becomes

$$-\log [P] = +\frac{a_p}{2.303}t + b_p \qquad (13)$$

The data presented in Table 1 were statistically analyzed to evaluate the significance of the proposed first-order reaction model, expressed by equation (13), for the transfer reaction (12).

Figure 1 illustrates the graphic representation of the data presented in Table 1 relating the logarithm of the steel's phosphorus content to the process time after meltdown. The resultant correlation coefficients of the linear regression equations are in the order of 0.98 (see Appendix), and the equations for the lines illustrated in Fig. 1 are:

A. $\log [P] = -0.00816t - 1.778$ (14′)
B. $\log [P] = -0.00397t - 1.942$ (15′)
C. $\log [P] = -0.00141t - 2.054$ (16′)
D. $\log [P] = -0.00490t - 2.067$ (17′)
E. $\log [P] = -0.00571t - 1.889$ (18′)
F. $\log [P] = -0.00218t - 2.049$ (19′)
G. $\log [P] = -0.00785t - 1.920$ (20′)
H. $\log [P] = -0.00302t - 1.723$ (21′)

These statistical results were then evaluated by employing the "student's -t" method and indicated the linear regression equations [(14′) - (21′)] are significant

at the 0.05 confidence level. Thus, dephosphorization during the oxidizing period of a basic-electric heat can be described as being first-order with respect to the steel's phosphorus content.

Further examination of the equations [(14') - (21')], illustrated in Fig. 1, shows that although the slopes of the equations are constant during each individual oxidizing period, i.e.,

$$-\frac{d \log [P]}{dt} = \frac{a_p}{2.303} \qquad (14)$$

they do vary in magnitude from heat to heat, i.e.,

$$\left[\frac{a_p}{2.303}\right]_A \neq \left[\frac{a_p}{2.303}\right]_B \neq \left[\frac{a_p}{2.303}\right]_C \qquad (15)$$

What condition, if any, existing in the furnace environment causes the difference in the slopes of these linear kinetic equations? Variation in metal and slag compositions from heat to heat may offer a partial answer to this question. Assuming the metal composition variable is insignificant and concentrating on the variation in slag compositions, it is evident that during the oxidizing period of a heat, the average dephosphorizing power, $\frac{(P)}{[P]} \equiv \frac{(\%\ \text{phosphorus in the slag})}{[\%\ \text{phosphorus in the metal}]}$, is a constant but does vary in magnitude from heat to heat, i.e.,

$$\left[\frac{(P)}{[P]}\right]_A = K_A \neq \left[\frac{(P)}{[P]}\right]_B = K_B \qquad (16)$$

Does the variation in the average dephosphorizing power parameter correlate with the change in the slope of the kinetic equations? i.e., is

$$\frac{d \log [P]}{dt} = f\left[\frac{(P)}{[P]}\right]? \qquad (17)$$

Assuming a linear relationship between these two parameters, we have

$$-\frac{d \log [P]}{dt} = k_1\left[\frac{(P)}{[P]}\right] + c_1 \qquad (18)$$

The data obtained, which are presented in Table 2 and graphically represented in Fig. 2, were statistically analyzed to evaluate the significance of equation (18) under actual basic-electric steel-making conditions. The linear regression analysis of the results yielded a correlation coefficient of 0.80 (see Appendix) and an equation for the line illustrated in Fig. 2:

$$-\frac{d \log [P]}{dt} = +0.000208\left[\frac{(P)}{[P]}\right] + 0.00035 \qquad (19)$$

Employment of the "student's -t" method to evaluate these statistical results indicated that equation (19) is significant at the 0.05 confidence level. Thus, the logarithmic rate of dephosphorization, which is constant during the oxidizing period of a basic-electric heat, increases linearly in magnitude from heat to heat with increasing values of the average dephosphorizing power. It can be seen that an increase in the magnitude of the average dephosphorizing power would then decrease the time required for maximum phosphorus removal from the steel.

TABLE 1 — PHOSPHORUS CONTENTS OF SEVERAL BASIC-ELECTRIC STEEL HEATS FROM MELTDOWN THROUGH OXIDIZING PERIOD

Heat No.	Type of Steel	Per cent Phosphorus in the Steel [%P]	Log [%P]	Time After Meltdown in Min (t)
A	A.I.S.I. 4140	0.022	−1.657	0
		0.008	−2.097	20
		0.004	−2.398	80
		0.001	−3.000	150
B	A.I.S.I. 4140	0.012	−1.921	0
		0.006	−2.097	30
		0.005	−2.301	95
		0.003	−2.523	145
C	A.I.S.I. 4140	0.009	−2.046	0
		0.008	−2.097	20
		0.007	−2.155	80
		0.006	−2.222	115
D	A.I.S.I. 4330	0.008	−2.097	0
		0.007	−2.155	20
		0.004	−2.398	80
		0.002	−2.699	120
E	A.I.S.I. 4330	0.011	−1.959	0
		0.010	−2.000	20
		0.008	−2.097	80
		0.002	−2.699	110
F	A.I.S.I. 4325	0.009	−2.046	0
		0.008	−2.097	20
		0.006	−2.222	80
		0.005	−2.301	115
G	A.I.S.I. 1040	0.011	−1.959	0
		0.009	−2.046	20
		0.003	−2.523	80
		0.001	−3.000	135
H	A.I.S.I. 4340	0.017	−1.770	0
		0.017	−1.770	15
		0.016	−1.796	30
		0.015	−1.824	45
		0.015	−1.824	59
		0.011	−1.959	77
		0.009	−2.046	90
		0.009	−2.046	104

In the literature it is stated that the dephosphorizing power is related to the slag composition by the relation

$$\frac{(P)}{[P]} = 0.776\left[\frac{(\%\ CaO)\,(\%\ FeO)}{(\%\ SiO_2)}\right]^{0.69} \qquad (20)$$

where

$\frac{(\%\ CaO)}{(\%\ SiO_2)}$ is the slag basicity.

(% FeO) is the slag oxidizing power.[6]

Thus, the logarithmic rate of dephosphorization can also vary linearly from heat to heat with respect to the average slag parameter, as suggested by:

$$-\frac{d \log [P]}{dt} = k_2\left[\frac{(\%\ CaO)\,(\%\ FeO)}{(\%\ SiO_2)}\right]^{0.69} + c_2 \qquad (21)$$

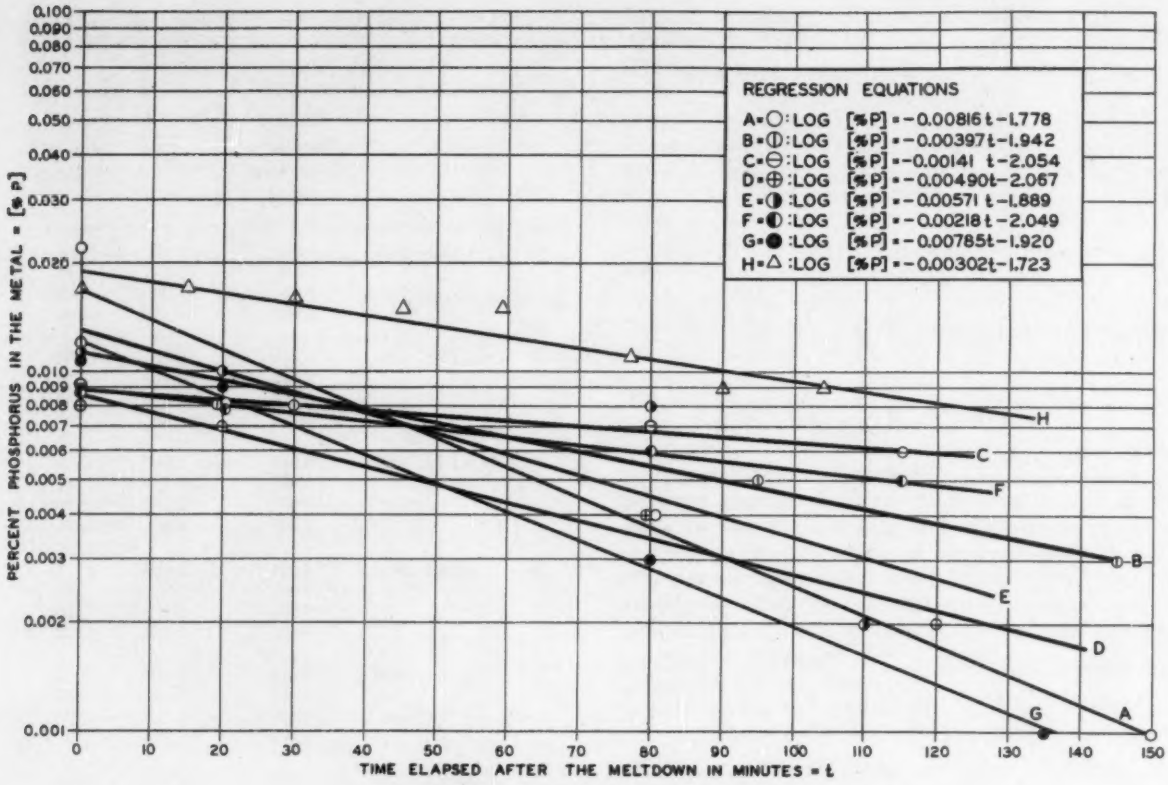


Fig. 1 — Influence of time elapsed after meltdown on the phosphorus content of steel used.

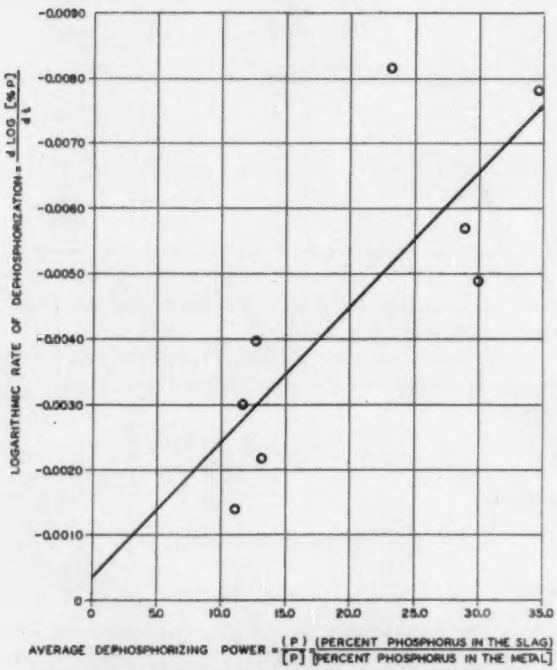


Fig. 2 — Relationship between average dephosphorization powers existing during the oxidizing periods of several basic-electric steel heats and the computed logarithmic rates of dephosphorization.

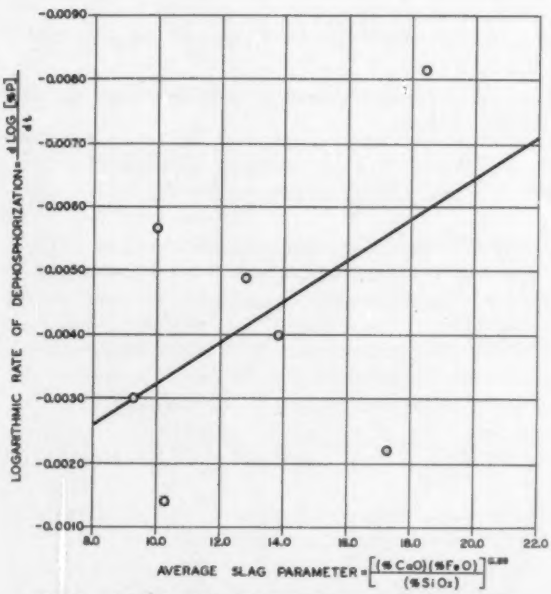


Fig. 3 — Relationship between the average slag parameter existing during the oxidizing periods of several basic-electric steel heats and the computed logarithmic rates of dephosphorization.

The data presented in Table 2, and graphically represented in Fig. 3, were statistically analyzed to evaluate the significance of equation (21) under actual basic-electric steelmaking conditions. The linear regression analysis of these results yielded a correlation coefficient of 0.609 (see Appendix) and the equation for the line illustrated in Fig. 3:

TABLE 2 — LOGARITHMIC RATES OF DEPHOSPHORIZATION, AVERAGE DEPHOSPHORIZING POWERS AND AVERAGE SLAG PARAMETERS FOR SEVERAL BASIC-ELECTRIC STEEL HEATS

Heat No.	Logarithmic Rate of Dephosphorization $\frac{d \log [\%P]}{dt}$	Avg. Dephosphorizing Power $\frac{(P)}{[P]}$	Avg. Slag Parameter $\frac{(\%CaO)(\%FeO)}{(\%SiO_2)}$	$\left[\frac{(\%CaO)(\%FeO)}{(\%SiO_2)}\right]^{0.69}$
A	−0.00816	23.2	68.7	18.51
B	−0.00397	12.7	45.4	13.91
C	−0.00141	11.2	29.5	10.33
D	−0.00490	29.9	40.4	12.84
E	−0.00571	28.8	28.2	10.01
F	−0.00218	13.2	62.2	17.29
G	−0.00785	34.6	91.7	22.60
H	−0.00302	11.7	25.2	9.33

$$-\frac{d \log [P]}{dt} = + 0.000321\left[\frac{(\%\ CaO)\,(\%\ FeO)}{(\%\ SiO_2)}\right]^{0.69} + 0.00004 \qquad (22)$$

The "student's -t" test revealed that equation (22) is insignificant at the 0.05 confidence level. Thus, the logarithmic rate of dephosphorization can not be shown to directly depend on the proposed slag variable in the above manner, but can only be said to increase in magnitude with increasing values of the average slag parameter.

Desulfurization occurs principally during the reducing period of a basic-electric heat. Taking the ith component as the element sulfur during this stage of the refining cycle, equation (11) can be written:

$$S_{metal} \rightarrow S_{slag} \qquad (23)$$

Equation (10) becomes:

$$-\log [S] = + \frac{a_s}{2.303} t + b_s \qquad (24)$$

The data presented in Table 3 were statistically analyzed to evaluate the significance of the proposed first-order reaction model under actual steelmaking conditions, as expressed by equation (24) for the transfer reaction (23).

Figure 4 graphically illustrates the data presented in Table 3 relating the logarithm of the steel's sulfur content to the process time after the shape-up of the reducing slag. The resultant correlation coefficients of the linear regression analyses are in the order of 0.90 (see Appendix), and the equations for the lines illustrated in Fig. 4 are:

TABLE 3 — SULFUR CONTENTS OF SEVERAL BASIC-ELECTRIC STEEL HEATS FROM SHAPE-UP OF REDUCING SLAG TO TAP

Heat No.	Type of Steel	Per cent Sulfur in the Steel [%S]	Log [%S]	Time After Shape-Up of the Reducing Slag in Min (t)
A	A.I.S.I. 4140	0.029	−1.537	0
		0.024	−1.620	10
		0.020	−1.699	20
		0.018	−1.745	50
		0.017	−1.770	66
B	A.I.S.I. 4140	0.033	−1.481	0
		0.024	−1.620	16
		0.028	−1.553	31
		0.026	−1.585	46
		0.022	−1.657	66
		0.019	−1.721	79
C	A.I.S.I. 4140	0.018	−1.745	0
		0.016	−1.796	15
		0.015	−1.824	30
		0.014	−1.854	45
		0.013	−1.886	61
D	A.I.S.I. 4330	0.014	−1.854	0
		0.011	−1.959	15
		0.012	−1.921	25
		0.009	−2.051	40
		0.008	−2.097	55
		0.007	−2.155	70
		0.005	−2.301	104
E	A.I.S.I. 4330	0.018	−1.745	0
		0.015	−1.824	15
		0.017	−1.770	30
		0.014	−1.854	45
		0.014	−1.854	60
		0.014	−1.854	75
		0.012	−1.921	90
F	A.I.S.I. 4325	0.017	−1.770	0
		0.014	−1.854	11
		0.012	−1.921	26
		0.011	−1.959	41
		0.011	−1.959	56
		0.011	−1.959	71
		0.011	−1.959	86
		0.010	−2.000	101
G	A.I.S.I. 4340	0.021	−1.678	0
		0.019	−1.721	20
		0.013	−1.886	44
		0.010	−2.000	59
		0.008	−2.097	74
		0.006	−2.222	94
		0.005	−2.301	101

A. $\log [S] = -0.00317t - 1.581$ (25)

B. $\log [S] = -0.00241t - 1.507$ (26)

C. $\log [S] = -0.00224t - 1.753$ (27)

D. $\log [S] = -0.00424t - 1.861$ (28)

E. $\log [S] = -0.00160t - 1.760$ (29)

F. $\log [S] = -0.00179t - 1.835$ (30)

G. $\log [S] = -0.00634t - 1.631$ (31)

Applying the "student's -t" test to these results proved

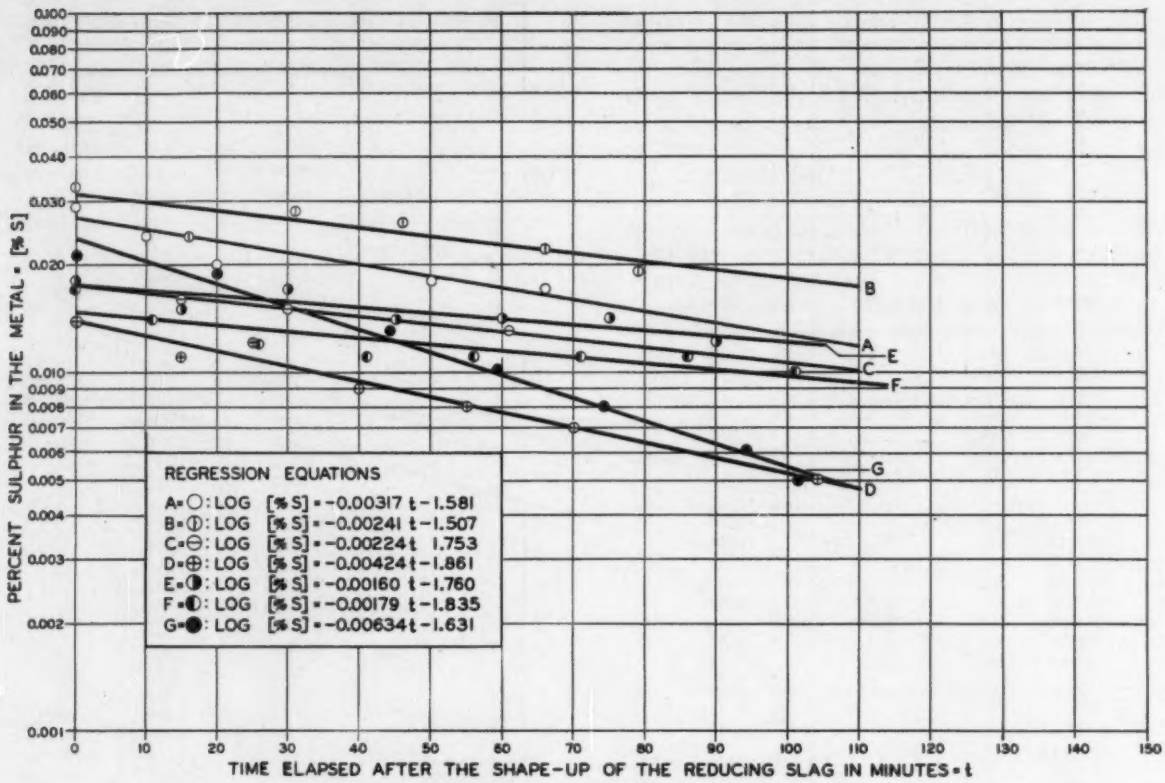

PERCENT SULPHUR IN THE METAL = [% S]
TIME ELAPSED AFTER THE SHAPE-UP OF THE REDUCING SLAG IN MINUTES = t
REGRESSION EQUATIONS
A=○: LOG [% S] = -0.00317 t - 1.581
B=①: LOG [% S] = -0.00241 t - 1.507
C=⊖: LOG [% S] = -0.00224 t 1.753
D=⊕: LOG [% S] = -0.00424 t - 1.861
E=◑: LOG [% S] = -0.00160 t - 1.760
F=◐: LOG [% S] = -0.00179 t - 1.835
G=●: LOG [% S] = -0.00634 t - 1.631
A
B
C
D
E
F
G

Fig. 4 — Influence of time elapsed after the shape up of the reducing slag on the sulfur content of steel used.

that the linear regression equations [(25) - (31)] are significant at the 0.05 confidence level. Thus, desulfurization during the reducing period of a basic-electric heat can be described by as being first-order with respect to the steel's sulfur content.

Further study of equations [(25) - (31)], and their graphic representation in Fig. 4, indicates that the slopes of the kinetic equations vary from heat to heat. Equation (32) offers a solution to explain this change in slope by stating that its magnitude may be a direct function of the average desulfurizing power $\left[\frac{(S)}{[S]}\right]$ existing throughout the reducing period of a basic-electric steel heat, i.e.,

$$-\frac{d \log [S]}{dt} = + k_3 \left[\frac{(S)}{[S]}\right] + c_3 \qquad (32)$$

The data presented in Table 4, and graphically represented in Fig. 5, were statistically analyzed to evaluate the significance of equation (32) under actual steelmaking conditions. The linear regression analysis yielded a correlation coefficient of 0.964 (see Appendix) and the equation for the line illustrated in Fig. 5:

$$-\frac{d \log [S]}{dt} = + 0.000379 \left[\frac{(S)}{[S]}\right] - 0.00120 \qquad (33)$$

The "student's -t" test indicated that equation (33) is significant at the 0.05 confidence level. Thus, the logarithmic rate of desulfurization, which is constant during the reducing period of a basic-electric heat, increases linearly in magnitude from heat to heat with increasing values of the average desulfurizing power. Also, an increase in the average desulfurizing power will decrease the time required for maximum sulfur removal from the steel.

Equation (34) proposes another variable which may affect the logarithmic rate of desulfurization during the reducing period of a basic-electric heat, namely, a slag parameter equal to the slag basicity divided by its oxidizing power, i.e.,

$$-\frac{d \log [S]}{dt} = + k_4 \left[\frac{(\%\ CaO)}{(\%\ SiO_2)\,(\%\ FeO)}\right]^{0.48} + c_4 \qquad (34)$$

(See reference 6).

The data presented in Table 4, and graphically represented in Fig. 6, were statistically analyzed to evaluate the significance of equation (34) under actual basic-electric steelmaking conditions. The linear regression analysis of these results yielded a correlation coefficient of 0.800 (see Appendix), and the equation for the line illustrated in Fig. 6:

$$-\frac{d \log [S]}{dt} = + 0.00376 \left[\frac{(\%\ CaO)}{(\%\ SiO_2)\,(\%\ FeO)}\right]^{0.48} - 0.00099 \qquad (35)$$

The "student's -t" test revealed that equation (35) is significant at the 0.05 confidence level. Thus, the logarithmic rate of desulfurization does increase in mag-

Fig. 5 — Relationship between the average desulfurization powers existing during the reducing periods of several basic-electric steel heats and the computed logarithmic rates of desulfurization.

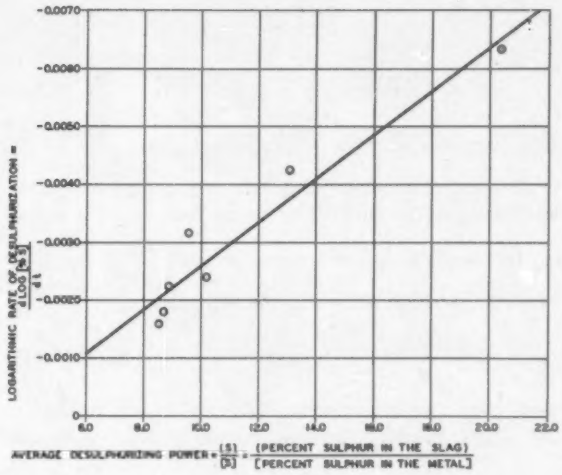


TABLE 4 — LOGARITHMIC RATES OF DESULFURIZATION, AVERAGE DESULFURIZING POWERS AND AVERAGE SLAG PARAMETERS FOR SEVERAL BASIC-ELECTRIC-STEEL HEATS

Heat No.	Logarithmic Rate of Desulfurization $\frac{d \log [\%S]}{dt}$	Avg. Desulfurizing Power $\frac{(S)}{[S]}$	Avg. Slag Parameter $\frac{(\%CaO)}{(\%SiO_2)(\%FeO)}$	$\left[\frac{(\%CaO)}{(\%SiO_2)(\%FeO)}\right]^{0.48}$
A	−0.00317	9.56	0.776	0.886
B	−0.00241	10.23	0.572	0.765
C	−0.00224	8.95	0.956	0.978
D	−0.00424	13.11	1.878	1.353
E	−0.00160	8.59	0.735	0.863
F	−0.00179	8.74	0.709	0.848
G	−0.00634	20.43		

nitude from heat to heat with increasing values of an average slag parameter, equal to the slag basicity divided by the slag oxidizing power, as indicated by equation (35).

This kinetic analysis of data generated in a 6½ ton basic-electric arc furnace produced realistic results which are hoped will aid the operating metallurgist to establish conditions that will affect the rapid removal of the detrimental elements phosphorus and sulfur from steel.

CONCLUSIONS

This investigation revealed that during the production of steel in a 6½ ton basic-electric arc furnace:

Dephosphorization, which occurs primarily during the oxidizing period of a heat and proceeds in accordance with the transfer reaction

$$P_{metal} \rightarrow P_{slag} \qquad (12)$$

is representative of a first-order type kinetic reaction with respect to the steel's phosphorus content as described by the equation,

$$-\log [P] = +\frac{a_P}{2.303} t + b_P \qquad (13)$$

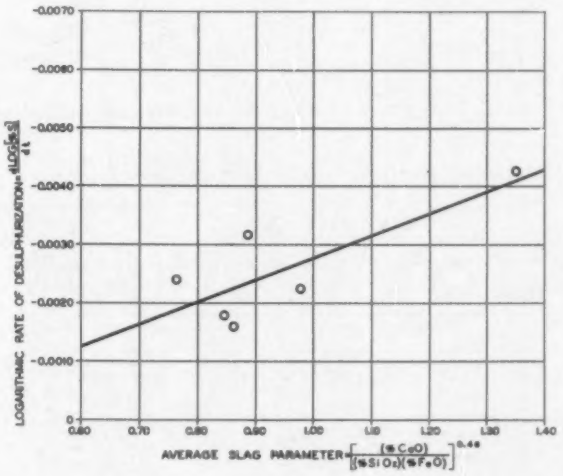
The logarithmic rate of dephosphorization $\left[\frac{d \log [P]}{dt}\right]$ is constant throughout the oxidizing period of a heat, but increases in magnitude from heat to heat when the average dephosphorizing power $\left[\frac{(P)}{[P]}\right]$ increases in value in accordance with the equation,

$$-\frac{d \log [P]}{dt} = +0.000208 \left[\frac{(P)}{[P]}\right] + 0.00035 \qquad (19)$$

Desulfurization, which occurs primarily during the reducing period of a heat, and proceeds in accordance with the transfer reaction

$$S_{metal} \rightarrow S_{slag} \qquad (23)$$

Fig. 6 — Relationship between an average slag parameter existing during the reducing periods of several basic-electric heats and the computed logarithmic rates of desulfurization.



is representative of a first-order type kinetic reaction with respect to the steel's sulfur content as described by the equation,

$$-\log [S] = +\frac{a_s}{2.303}\,t + b_s \qquad (24)$$

The logarithmic rate of desulfurization $\left[\frac{d \log [S]}{dt}\right]$ is constant throughout the reducing period of a heat, but increases in magniture from heat to heat when, a), the average desulfurizing power $\left[\frac{(S)}{[S]}\right]$ increases value in accordance with the equation

$$-\frac{d \log [S]}{dt} = +0.000379\left[\frac{(S)}{[S]}\right] - 0.00120 \qquad (33)$$

and, b), the average slag parameter equal to the slag's basicity divided by its oxidizing power $\left[\frac{(\%\ CaO)}{(\%\ SiO_2)\,(\%\ FeO)}\right]$ increases in value in accordance with the equation,

$$-\frac{d \log [S]}{dt} = + 0.00376\left[\frac{(\%\ CaO)}{(\%\ SiO_2)\,(\%\ FeO)}\right]^{0.48} - 0.00099 \qquad (35)$$

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APPENDIX

Linear Regression Analyses of Basic-Electric Steelmaking Data Showing Influence of Time Elapsed After Meltdown on Steel's Phosphorus Content

Y = Log [%P] = Log [Per cent Phosphorus in the Steel]. (see Table 1)

X = t = Time Elapsed after Meltdown in Min. (see Table 1)

Summation results:

Heat	$\bar{Y} = \frac{\Sigma Y}{N}$	$\bar{X} = \frac{\Sigma X}{N}$	$\frac{\Sigma(Y-\bar{Y})}{N}$	$\frac{\Sigma(X-\bar{X})}{N}$	$\frac{\Sigma(Y-\bar{Y})^2}{N}$	$\frac{\Sigma(Y-\bar{Y})(X-\bar{X})}{N}$	$\frac{\Sigma(X-\bar{X})^2}{N}$
A	−2.288	62.5	0	0	+0.238422	−27.9450	+3418.75
B	−2.210	67.5	−0.0005	0	+0.050635	−12.62625	+3181.25
C	−2.130	53.8	0	−0.05	+0.0043085	− 2.9800	+2117.19
D	−2.337	55.0	−0.0002	0	+0.056372	−11.15625	+2275.00
E	−2.189	52.5	−0.0002	0	+0.089296	−11.253125	+1968.75
F	−2.166	53.8	−0.0004	−0.04	+0.010130	− 4.62935	+2117.19
G	−2.382	58.8	0	−0.04	+0.173408	−21.9975	+2804.69
H	−1.879	52.5	−0.0004	0	+0.012360	− 3.56944	+1178.25

Correlation Coefficient (r) and Regression Equations:

Heat	$r = \frac{\frac{\Sigma(Y-\bar{Y})(X-\bar{X})}{N}}{\sigma_y \quad \sigma_x}$	$\sigma_y = \left[\frac{\Sigma(Y-\bar{Y})^2}{N}\right]^{1/2}$	$\sigma_x = \left[\frac{\Sigma(X-\bar{X})^2}{N}\right]^{1/2}$	Reg. Eq.: $(Y-\bar{Y}) = \frac{r\sigma_y}{\sigma_x}(X-\bar{X})$
A	−0.978	0.4883	58.5	Log [%P] = −0.00816t − 1.778
B	−0.995	0.225	56.4	Log [%P] = −0.00397t − 1.942
C	−0.995	0.0651	46.0	Log [%P] = −0.00141t − 2.054
D	−0.985	0.2374	47.7	Log [%P] = −0.00490t − 2.067
E	−0.848	0.2988	44.4	Log [%P] = −0.00571t − 1.889
F	−0.999	0.1007	46.0	Log [%P] = −0.00218t − 2.049
G	−0.998	0.4164	53.0	Log [%P] = −0.00785t − 1.920
H	−0.993	0.1112	34.4	Log [%P] = −0.00302t − 1.723

Linear Regression Analysis of Data Showing Relationship Between Average Dephosphorizing Powers Existing During Oxidizing Periods of Several Basic-Electric Steel Heats and Computed Logarithmic Rates of Dephosphorization

$Y = \frac{d\,Log\,[\%P]}{dt}$ = Logarithmic Rate of Dephosphorization (see Table 2)

$X = \frac{(P)}{[P]}$ = Average Dephosphorizing Power (see Table 2)

Summation Results:

1. $\bar{Y} = \frac{\Sigma Y}{N} = -0.00465$
2. $\bar{X} = \frac{\Sigma X}{N} = 20.7$
3. $\frac{\Sigma (Y-\bar{Y})}{N} = 0$
4. $\frac{\Sigma (X-\bar{X})}{N} = -0.04$
5. $\frac{\Sigma (Y-\bar{Y})^2}{N} = +0.000005433$
6. $\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N} = 0.0166945$
7. $\frac{\Sigma (X-\bar{X})^2}{N} = +80.15125$

Correlation Coefficient – (r):

$$r = \frac{\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N}}{\sigma_y \quad \sigma_x} = -0.800$$ where: $\sigma_y = 0.002331$ and $\sigma_x = 8.953$

Regression Equation: $(Y-\bar{Y}) = \frac{r\sigma_y}{\sigma_x}(X-\bar{X})$

$$\frac{d\,Log\,[\%P]}{dt} = -0.000208\left[\frac{(P)}{[P]}\right] - 0.00035$$

Linear Regression Analysis of Data Showing Relationship Between an Average Slag Parameter Existing During Oxidizing Periods of Several Basic-Electric Steel Heats and Computed Logarithmic Rates of Dephosphorization

$Y = \frac{d\,Log\,[\%P]}{dt}$ = Logarithmic Rate of Dephosphorization (see Table 2)

$X = \left[\frac{(\%\,CaO)(\%\,FeO)}{(\%\,SiO_2)}\right]^{0.69}$ = Average Slag Parameter (see Table 2)

Summation Results:

1. $\bar{Y} = \frac{\Sigma Y}{N} = -0.00465$
2. $\bar{X} = \frac{\Sigma X}{N} = 14.35$
3. $\frac{\Sigma (Y-\bar{Y})}{N} = 0$
4. $\frac{\Sigma (X-\bar{X})}{N} = +0.0025$
5. $\frac{\Sigma (Y-\bar{Y})^2}{N} = +0.000005433$
6. $\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N} = -0.062835625$
7. $\frac{\Sigma (X-\bar{X})^2}{N} = +19.585225$

Correlation Coefficient – (r):

$$r = \frac{\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N}}{\sigma_y \quad \sigma_x} = -0.609$$ where: $\sigma_y = 0.002331$ and $\sigma_x = 4.425$

Regression Equation: $(Y-\bar{Y}) = \frac{r\sigma_y}{\sigma_x}(X-\bar{X})$

$$\frac{d\,Log\,[\%P]}{dt} = -0.000321\left[\frac{(\%\,CaO)(\%\,FeO)}{(\%\,SiO_2)}\right]^{0.69} - 0.00004$$

Linear Regression Analyses of Basic-Electric Steelmaking Data Showing Influence of Elapsed After Shape-Up of Reducing Slag on Steel's Sulfur Content

$Y = Log\,[\%S] = Log$ [Per cent Sulfur in the Steel]. (see Table 3)

$X = t =$ Time Elapsed after the Shape up of the Reducing Slag in Min. (see Table 3)

Summation Results:

Heat	$\bar{Y} = \frac{\Sigma Y}{N}$	$\bar{X} = \frac{\Sigma X}{N}$	$\frac{\Sigma (Y-\bar{Y})}{N}$	$\frac{\Sigma (X-\bar{X})}{N}$	$\frac{\Sigma (Y-\bar{Y})^2}{N}$	$\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N}$	$\frac{\Sigma (X-\bar{X})^2}{N}$
A	−1.674	29.2	−0.0002	0	+0.007313	−1.96256	+618.56
B	−1.603	39.7	+0.0002	−0.013	+0.005806	−1.803283	+748.22
C	−1.821	30.2	0	0	+0.002345	−1.0330	+462.16
D	−2.048	44.1	−0.0003	+0.043	+0.019936	−4.5741	+1078.70
E	−1.832	45.0	+0.0003	0	+0.002976	−1.4400	+900.00
F	−1.923	49.0	+0.0004	−0.125	+0.004911	−2.027625	+1132.625
G	−1.986	56.0	−0.0004	0	+0.04893243	−7.59586	+1196.86

Correlation Coefficient (r) and Regression Equations:

Heat	$r = \frac{\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N}}{\frac{X}{\sigma_y \quad \sigma_x}}$	$\sigma_y = \left[\frac{\Sigma(Y-\bar{Y})^2}{N}\right]^{1/2}$	$\sigma_x = \left[\frac{\Sigma(X-\bar{X})^2}{N}\right]^{1/2}$	Reg. Eq.: $(Y-\bar{Y}) = \frac{r\sigma_y}{\sigma_x}(X-\bar{X})$
A	−0.923	0.0855	24.87	$\text{Log}\,[\%S] = -0.00317t - 1.581$
B	−0.865	0.0762	27.35	$\text{Log}\,[\%S] = -0.00241t - 1.507$
C	−0.993	0.0484	21.50	$\text{Log}\,[\%S] = -0.00224t - 1.753$
D	−0.986	0.1412	32.84	$\text{Log}\,[\%S] = -0.00424t - 1.861$
E	−0.879	0.0546	30.00	$\text{Log}\,[\%S] = -0.00160t - 1.760$
F	−0.859	0.0701	33.66	$\text{Log}\,[\%S] = -0.00179t - 1.835$
G	−0.992	0.2212	34.60	$\text{Log}\,[\%S] = -0.00634t - 1.631$

Linear Regression Analysis of Data Showing Relationship Between Average Desulfurizing Powers Existing During Reducing Periods of Several Basic-Electric Steel Heats and Computed Logarithmic Rates of Desulfurization

$Y = \frac{d\,\text{Log}\,[\%S]}{dt}$ = Logarithmic Rate of Desulfurization (see Table 4)

$X = \frac{(S)}{[S]}$ = Average Desulfurizing Power (see Table 4)

Summation Results:

1. $\bar{Y} = \frac{\Sigma Y}{N} = -0.00311$
2. $\bar{X} = \frac{\Sigma X}{N} = 11.37$
3. $\frac{\Sigma (Y-\bar{Y})}{N} = +0.000003$
4. $\frac{\Sigma (X-\bar{X})}{N} = +0.003$
5. $\frac{\Sigma (Y-\bar{Y})^2}{N} = +0.000002426114$
6. $\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N} = 0.005956314$
7. $\frac{\Sigma (X-\bar{X})^2}{N} = +15.7412285$

Correlation Coefficient – (r):

$$r = \frac{\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N}}{\frac{X}{\sigma_y \quad \sigma_x}} = -0.964 \text{ where: } \sigma_y = 0.001558 \text{ and } \sigma_x = 3.967$$

Regression Equation: $(Y-\bar{Y}) = \frac{r\sigma_y}{\sigma_x}(X-\bar{X})$

$$\frac{d\,\text{Log}\,[\%S]}{dt} = -0.000379\left[\frac{(S)}{[S]}\right] + 0.00120$$

Linear Regression Analysis of Data Showing Relationship Between an Average Slag Parameter Existing During Reducing Periods of Several Basic-Electric Steel Heats and Computed Logarithmic Rates of Desulfurization

$Y = \frac{d\,\text{Log}\,[\%S]}{dt}$ = Logarithmic Rate of Desulfurization (see Table 4)

$X = \left[\frac{(\%\,CaO)}{(\%\,SiO_2)(\%\,FeO)}\right]^{0.48}$ = Average Slag Parameter (see Table 4)

Summation Results:

1. $\bar{Y} = \frac{\Sigma Y}{N} = -0.00258$
2. $\bar{X} = \frac{\Sigma X}{N} = 0.949$
3. $\frac{\Sigma (Y-\bar{Y})}{N} = 0.000005$
4. $\frac{\Sigma (X-\bar{X})}{N} = 0.0002$
5. $\frac{\Sigma (Y-\bar{Y})^2}{N} = +0.00000080545$
6. $\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N} = 0.0001373267$
7. $\frac{\Sigma (X-\bar{X})^2}{N} = 0.03657983$

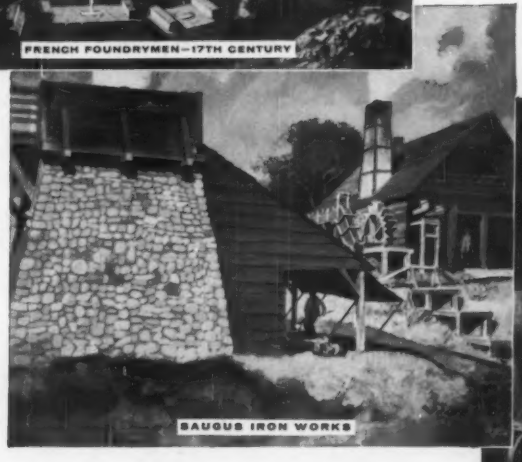
Correlation Coefficient – (r):

$$r = \frac{\frac{\Sigma (Y-\bar{Y})(X-\bar{X})}{N}}{\frac{X}{\sigma_y \quad \sigma_x}} = -0.800 \text{ where: } \sigma_y = 0.000898 \text{ and } \sigma_x = 0.1913$$

Regression Equation: $(Y-\bar{Y}) = \frac{r\sigma_y}{\sigma_x}(X-\bar{X})$

$$\frac{d\,\text{Log}\,[\%S]}{dt} = -0.00376\left[\frac{(\%\,CaO)}{(\%\,SiO)(\%\,FeO)}\right]^{0.48} + 0.00099$$

Gray Iron Foundry Milestones



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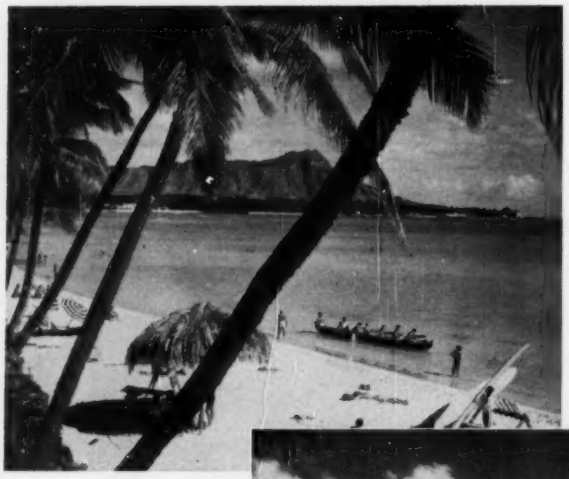

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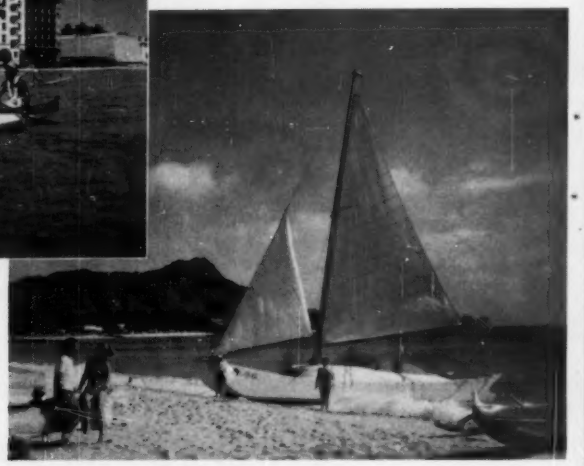

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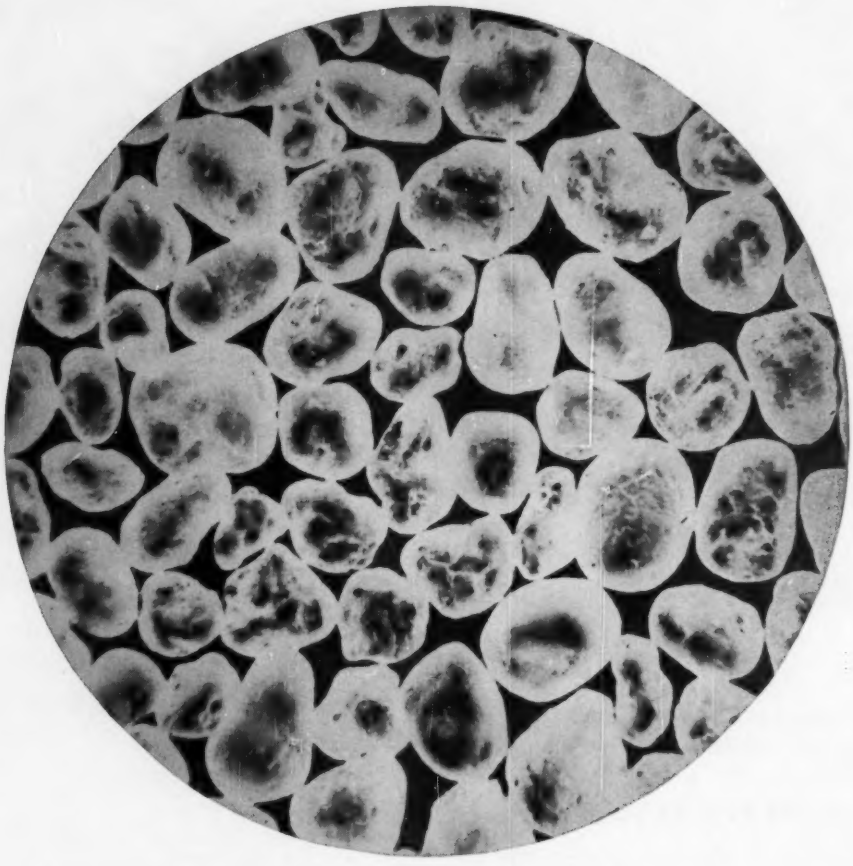
Address_____

City_____ State_____



The sand in the microphoto above speaks quality. It's pure and fine, with the excellent rounded grain properties so desired for foundry use. This is indeed a superb sand—finest for foundries.

The obvious merits of quality can be yours with Wedron Silica

Send for illustrated brochure on Wedron sands.

Circle No. 129, pages 157-158

65th CASTINGS CONGRESS

AFS CONVENTION NEWS

SAN FRANCISCO, MAY 8-12, 1961

SUPPLIES & EQUIPMENT EXPOSITION

1961 Convention Features Full-Scale Show with Operating Exhibits

Exhibitor applications continue to flow into AFS Headquarters for the AFS 1961, full-scale Exposition to be held May 8-12 in San Francisco.

This is a full-scale operating Exposition of foundry equipment, materials, supplies, and services. It is *not* an Engineered Castings Show.

According to AFS Convention and Exhibit Manager Dick Hewitt, space assignments are rapidly being made for this full-scale exhibit, with the earliest applications receiving priority.

A complete range of foundry equipment, processes, and materials will be on exhibit. The Show in character will be similar to the 1960 Exposition held in Philadelphia.

Significance of the San Francisco site reflects the progress being made in the West Coast metal processing industries and in the established demand for an industry-wide Exposition of metalcasting equipment and supplies.

Two factors contribute to make this a dynamic area of the metalcasting industry—progressive foundries and an increased population that now totals 25,000,000 and is still growing. Also the region now has 14 per cent of the nation's foundry population which continues to expand.

Hewitt points out the progressive nature of the far west foundries is shown in the industries they serve. For example, the aircraft and missile industries, alone, are big consumers of high quality castings. There are more foundries in this region catering to the aerodynamics industry than in any other section of the country.

Hewitt emphasizes that this is a prime market, one that has not been previously exposed to a national metalcasting Exposition and the West Coast is enthusiastically supporting the Show.

Brooks Hall, site of the Exposition, has several outstanding features. It is new, underground, fully air-conditioned, and has major facilities for air, gas, exhaust, drains, water, and power.

Operating exhibits, demonstration areas, and theaters will be planned so that there is a smooth flow of traffic throughout the entire hall.

Also the hall is directly connected to the Civic Auditorium where the technical sessions will be conducted. Both the Castings Congress and the Exposition will run concurrently.

Hewitt urges that exhibitors man the booth adequately and continuously to better serve the visitors and that they follow up leads after the Show to offer continued assistance.

Present Ethics Plan to F.E.M.A.

The Foundry Equipment Manufacturers' Association gave a very warm reception to the AFS code of ethics for industrial and trade shows.

The plan, spearheaded by AFS, was presented at the annual meeting by AFS President N. J. Dunbeck, International Minerals & Chemical Corp., Skokie, Ill., and AFS General Manager Wm. W. Maloney.

Details of the plan were outlined in the November issue of MODERN CASTINGS.

1961 Convention Draws from Europe

M. Klemmer, Croning & Co., Hamburg-Rissen, Germany, has announced that he will attend the AFS 65th Convention in San Francisco.

This trip will involve 5657 miles.

Says Sam Russell, chairman of the AFS Northern California Chapter, host to the Convention, "We hope that we can get him to Hawaii for the adjourned session and post-Congress tour. He will then have traveled halfway around the world, garnering metalcasting technology."

Plan Extensive Technical Program

Plans by the various technical divisions and general interest committees indicate a well-balanced, extensive program for the 1961 Castings Congress.

Several divisions report that planning is running ahead of a year ago at this time. In addition to the technical papers, a well-rounded shop course program will be held at night.

Name Adjourned Session Speaker

George Mason, Director, Department of Economic Development, will be the featured speaker at the concluding session of the 65th Castings Congress & Exposition to be held in Honolulu, Hawaii, May 15.

See pages 118-119 for details on the Hawiian tours.

Show Hours

Official hours for the 1961 AFS Exposition are:

Monday	**May 8**
9:00 am to 5:30 pm	
Tuesday	**May 9**
9:00 am to 5:30 pm	
Wednesday	**May 10**
11:00 am to 5:30 pm	
Thursday	**May 11**
9:00 am to 5:30 pm	
Friday	**May 12**
9:00 am to 5:00 pm	

Name Host Committee Officials

S. D. Russell, Phoenix Iron Works, Oakland, Calif., has been named Chairman of the Host Chapter Committee of the Northern California Chapter, hosts to the 65th Castings Congress & Exposition.

John R. Russo, Russo Foundry Equipment Co., Oakland, is co-chairman and Davis Taylor, Wheelabrator Corp., San Carlos, Calif., is secretary-treasurer.

Other host chapter members and the committees they head are:

Hospitality—Donald C. Caudron, Pacific Brass Foundry of San Francisco, San Francisco.

Plant Visitation—Charles R. Marshall, Industrial & Foundry Supply Co., Oakland.

Shop Course—Robert A. Johnston, Brumley-Donaldson Co., San Leandro.

Ladies Activities—Clayton D. Russell, Phoenix Iron Works, Oakland.

Banquet—Lane M. Currie, H. C. Macaulay Foundry, Berkeley.

Publicity—J. M. Snyder, National Abrasive Co., Castro Valley.

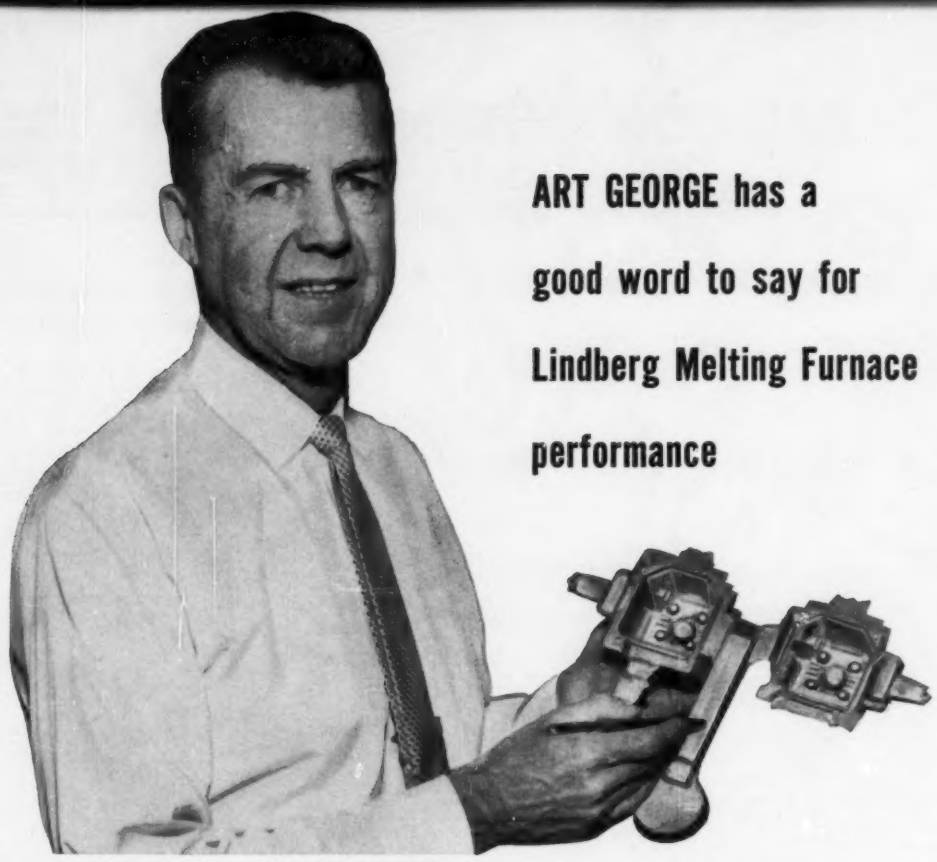
Northern California Day—Hugh F. Prior, Superior Electrocast Foundry Co. San Mateo.

D. Taylor

J. R. Russo

S. D. Russell

ART GEORGE has a good word to say for Lindberg Melting Furnace performance

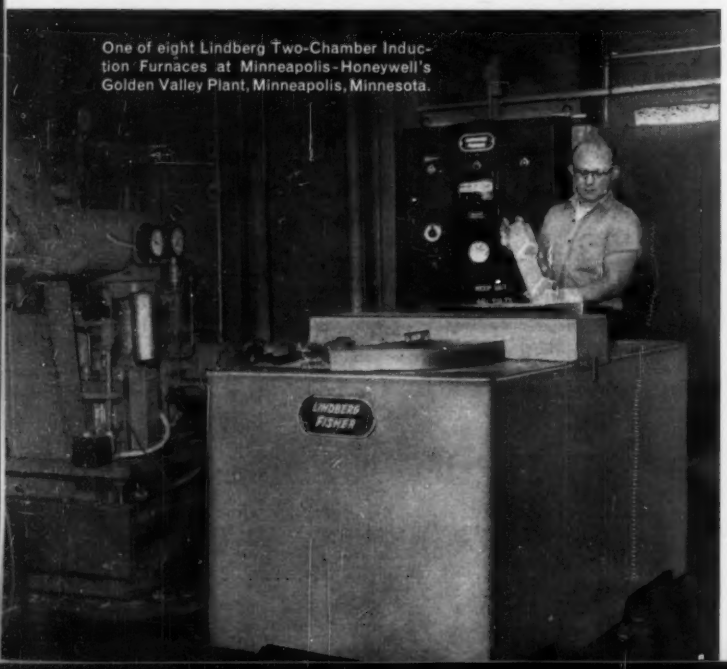


QUOTE

Mr. Art George, Senior Production Engineer, Golden Valley Plant, Minneapolis-Honeywell Regulator Company, Minneapolis, Minn.

"Our installation of eight* Lindberg-Fisher Two-Chamber Induction Melting and Holding Furnaces has given remarkable service for more than four years. In this period, with the help of a well executed Honeywell maintenance program, the installation has been unusually trouble-free. Only one of the eight furnaces has required relining over this long period. Handling more than 1,000,000 pounds of aluminum and zinc annually, the installation has unfailingly provided the consistently high quality of metal our precision instruments require."

**Altogether, 44 Lindberg Furnaces are in operation in various Honeywell plants.*



One of eight Lindberg Two-Chamber Induction Furnaces at Minneapolis-Honeywell's Golden Valley Plant, Minneapolis, Minnesota.

These eight Lindberg-Fisher Induction Furnaces melt and hold aluminum and zinc for die casting gas valve housings and other component parts. They are located at the die casting machines where ingot and scrap can be melted and held at the desired casting temperature in one convenient unit. Magnetic fluxing and stirring insures uniform temperatures and consistently clean metal.

In any production process where aluminum needs heat there is Lindberg equipment to apply it most economically and efficiently. Furnaces for melting and holding, casting stations, re-melting or heat treating are available in all capacities, electric or fuel fired. Get in touch with your Lindberg Field Engineer (see your classified phone book) or write us direct. Lindberg-Fisher Division, Lindberg Engineering Company, 2440 West Hubbard St., Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, South Africa, Spain, Switzerland and West Germany.

LINDBERG
heat for industry

NEWS and VIEWS

Conferences Alert Foundrymen
Exposition a Full-Scale Show
Apprentice Contest Expands

Now You Can Be Fashionable! Look Smart! Be Safe!

Safety equipment is now comfortable, attractive, and efficient. This was the tenor of the recent National Safety Exposition in Chicago.

The safe dressed foundryman looks neat and purposeful from the top of his head to the tip of his toes—in tune with the latest styles. Besides overcoming the mental-block of worker resentment too often associated with wearing safety clothing, management is now less reluctant to set the example so necessary for a successful safety program. The presidents of many progressive foundries wear the same safety clothing required of their workers—but styled to suit their tastes.

What does the well-dressed safe-dressed foundry worker wear? More likely than not he will be wearing—a bright colored, lightweight plastic helmet with built-in sweat band; prescription ground safety goggles with color and style of rims to suit his taste; a comfortable aluminized rayon jacket to reflect heat; flame proofed trousers that shed sparks like a duck sheds water; and safety shoes in any style to match the season or personal preference, which can also be worn to church or to a dance.

It's not hard to get workers to wear protective clothing when it is comfortable and looks neat.

Safety programs in the foundry industry need modernization just as frequently as any production activity. To help you measure up to par in safety MODERN CASTINGS describes here the latest in safety equipment. Literature is available on every one of these subjects. Just write the Editor of MODERN CASTINGS specifying what subjects you want.

Safety Hats and Caps . . . These hard hats now come in three materials—fibre glass for maximum strength, aluminum for best heat reflectivity, and polyethylene for protection from electrical shock. The fibre glass hats come in a variety of colors (even phosphorescent) so you can color code the workers by job functions. This innovation makes it easy to quickly locate a maintenance man, a pour-off man, fork lift operator, etc. All these hats have a new contour-adhering pliable polyethylene suspension that gives "soft hat" comfort with no hat wobble or top-heavy feeling. This inner support is adjustable to any head-size. A space of 1-1/4 inches clearance exists between hard outer surface and the inner

Course Stresses Sand Principles

Intensive, personalized instruction in sand testing procedures was given students attending the AFS Training & Research Institute course. The program was conducted in the laboratories of Harry W. Dietert Co., Detroit.

Students were divided into five teams and rotated through nine major interest areas. Among subjects covered were: base properties, molding sand properties, hot properties, core sand testing techniques, and latest shell sand testing methods.

The course was supplemented by a tour of the foundry facilities of the Cadillac Motor Car Div., General Motors Corp.

Instructors from Harry W. Dietert Co. were Alex Graham, Tom Hanna, Ray Daksiewicz, and Jess Toth. Others were Victor M. Rowell, Archer-Daniels-Midland Co., Cleveland, and Wayne H. Buell, Aristo Corp., Detroit.

Group studies with instructor Ray Daksiewicz, in shop coat. Others are V. C. Meier, Rock Island, Ill.; J. F. McMullin, Tabor Mfg. Co. Div., Turbo Machine Co., Lansdale, Pa.; Earl McKay, Sibley Machine & Foundry Corp., South Bend, Ind.; G. F. Neville, International Minerals & Chemical Co., Jackson, Ohio; and E. C. McKinley, Rock Island Arsenal.

← Circle No. 130, pages 157-158

support. Sweatband removes easily via its plastic zipper. For cold weather comfort a washable twill-flannel liner is available.

Safety Glasses, Goggles, and Face Shields . . . Probably the first step in any safety program is eye protection. An additional bonus results today when safety glasses are used because most of them are prescription ground. This means a big improvement in visibility leading to greater work accuracy. Frames for safety glasses come in all styles and materials so employees can wear them anywhere. Some of the new features available are: acetate frames, rigid or adjustable nose pads, wider field of vision, attachable side shields, and metal frames. Safety glasses available for special functions in the foundry are: split lenses (lower half clear, upper half colored for looking at hot metal), melter's glasses with leather covered bridge, and chipper's and welder's cup type goggles contoured to the head (10 different shades of high impact lens).

For taking care of visitors there is now an inexpensive one piece, light weight eyeshield that fits all faces, is impact resistant, and can be worn over glasses. It is designed as a give-away item for visitor to take home as a souvenir.

A new foundry goggle is mounted in a soft plastic mask and protects against chipping, melting, pouring, grinding and other dangerous activities. Another innovation is the lift-front goggle for men working intermittently around hot metal. Dark lens is hinged on top of clear safety glasses so it can be quickly flipped down to cover top half of clear lens.

A goggle that attaches to fibre glass hard-hat is handy for the man who needs only occasional eye protection. Adjustable telescoping aluminum arms hold the goggles against the face when in use or let goggle be raised and held against helmet when not needed.

For the worker around molten metal who needs complete face protection the latest good news is an aluminized plastic face shield. Thin aluminized coating on the plastic shield reflects over 80 per cent of radiant heat, leading to greater worker comfort. And the plastic shield lasts four times longer than conventional uncoated one.

Another interesting variation in face shields involves the type using a 24 mesh screen instead of plastic. Now the area in front of the eyes has a clear acetate window. Worker has unobstructed vision far superior to looking through a screen.

Ear Protectors . . . Many areas in the foundry emit harmful high frequency noises that permanently damage hearing. Comfortable inexpensive ear protectors are available to attenuate these noises at levels as high as 130 decibels. Yet the worker, when spoken to, can hear the human voice without removing the protection.

Since ear damage is a compensable injury, foundries are also looking at equipment designed to test workers for hearing loss. Audiometers are available for testing employees hearing and also for measuring noise levels and characteristics within the plant.

Gloves . . . Hands are being protected by gloves custom-designed to fit most any special requirement. Individual fingers are protected with finger guards that cover end, sides, front and back of each finger. Styles include 5 finger gloves, steel stitched glove, gauntlets, palm-wing thumb gloves, mittens, reversible mittens, one finger mittens, and hand pads. Glove materials include cowhide, horsehide, asbestos, wool, and cotton duck.

Protective Clothing . . . The big emphasis in protective clothing is focused on aluminized fabrics which reflect more than 90 per cent of radiant heat. The base fabrics may be asbestos, rayon, or cotton duck. The light weight of the clothing reduces worker fatigue, increases productivity, and permits mobility on the job. It sheds molten metal splash and spatter.

Besides worker protection during molten metal handling and heat treatment, aluminized clothing has made it possible to enter hot furnaces for short periods of time to make emergency adjustments or repairs. The coating does not peel or crack and it protects the base fabric yielding longer life than would be normal with plain uncoated asbestos. The following items of apparel are available in aluminized fabrics: jackets, coats, pants, chaps, aprons, spats, leggings, sleeves, cape sleeves, overalls, coveralls, hoods, gloves, and mittens.

Safety Shoes . . . Style conscious workers now have available almost as many shoe styles to choose from as any Christmas shopper. Safety shoes can now be casual in style, lightweight (15 ounces), and crepe soled, yet still have steel shank and box, resist acids and alkalis, and repel water. Fashionable styles can be had by women workers. Most workers wear their safety shoes when away from the shop and find they outwear non-safety shoes.

This completes our MODERN CASTINGS top-of-the-head to tip-of-the-toe safe worker survey. Literature describing further details on any of these items discussed can be yours for the asking by writing MODERN CASTINGS.

Society Issues Technical Roster

A roster of some 650 top technical men from all fields of the foundry industry has just been published by AFS.

The 1960-61 National Committee Personnel lists the divisions, plus the men who are working on technical divisions and general interest committees.

Divisions represented are: light metals, brass and bronze, education, gray iron, malleable, pattern, sand, steel, die casting and permanent mold, and ductile iron.

General interest committees include: fundamental papers, heat transfer, plaster mold casting, industrial engineering and cost, plant and plant equipment, refractories manual, cupola advisory, management development, and safety, hygiene and air pollution control.

Kiesler Authors Exchange Paper

"Melting Practice to Produce Extra Low-Sulfur Steel," by A. J. Kiesler, metallurgy and ceramics research department, General Electric Research Laboratory, Schenectady, N. Y., will be the official AFS exchange paper to the 28th International Foundry Congress. The international meeting will be held June 18-24, 1961, in Vienna, Austria.

Four Metallurgists Join Editorial Staff

Four outstanding metallurgists have been added to the editorial staff of MODERN CASTINGS, as contributing editors. These men, each of whom will represent the magazine in his geographical area, are experts in their fields. They are:

M. C. Flemings, assistant professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

W. D. McMillan, foundry consultant, Ohio Ferro Alloys Corp., Chicago.

J. S. Vanick, retired metallurgist, International Nickel Co., New York.

J. F. Wallace, associate professor of Metallurgical Engineering, Case Institute of Technology, Cleveland.

In making the announcement, Harold E. Green, managing director of the magazine, said the increase in staff is just one more step MODERN CASTINGS has taken to bring technology-for-profit into focus for the metalcasting industry.

Apprentice Contest Draws New Companies

Increased interest in the national apprentice contest is indicated by an unusual number of new company entries. AFS Education Director R. E. Betterley reports that the number of participants is running ahead of last year at this time and that a great number of companies are joining for the first time.

Betterley urges early participation by all companies and chapters sponsoring contests.

Entries for national judging must be received in Chicago by March 31. Local contests should be completed at least two weeks earlier.

In the national competition, three prizes are given for each of the five divisions. First place winners receive $100, second place, $75, and third place, $50. In addition, the five first place winners will have their round-trip travel expense paid to and from San Francisco, site of the 1961 Convention. All other expenses are to be assumed by the winner, his company, or chapter.

Age has no bearing on eligibility. The only requirements are that entrants have no more than five years patternmaking experience and no more than four years molding experience.

Meeting in Chicago, recently, Executive and Program & Papers Committees of the Ductile Iron Division developed plans for its technical sessions for the 1961 Convention in San Francisco.

Sand Division Heat Treating Committee met recently to map plans for future activities. Chairman C. R. Sorenson, National Malleable & Steel Castings Co., Cicero, Ill., presided.

Materials Used in Malleable Foundries Committee at a meeting held at AFS Headquarters discussed results of experiments conducted earlier this year.

Planning of AFS Training & Research Institute courses for the coming year was done at a recent meeting of the T&RI Course Advisory Committee. Shown are T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., Skokie, Ill.; H. H. Wilder, Vanadium Corp. of America, Chicago; T&RI Director S. C. Massari; T&RI Training Supervisor, R. E. Betterley; and E. Trela, Apex Smelting Co., Cleveland. Not shown is T. T. Lloyd, Albion Malleable Iron Co., Albion, Mich.

Conferences Call for Quality

Business outlook is optimistic despite curtailed operations at present. Future calls for improved casting quality and aggressive merchandising.

WARNINGS TO foundrymen that the industry must modernize and mechanize more, and become increasingly aware of quality and controls, were voiced at five recent regional foundry conferences.

Speakers from within and outside of the industry emphasized to management that customers are increasing their demands for uniformity, closer tolerances, and improved physical and mechanical properties. Metalcasters face a real challenge not only to increase their competitive position but to retain their share of the market.

How this can be done was outlined in the technical sessions designed to fit the needs of each area. Some found the solutions in coming technological developments, others in the new processes now available, but the majority placed the solution in better utilization of available research and techniques.

In general, foundries in these areas were operating under capacity. Significantly the over-all business outlook indicates some optimism. A special MODERN CASTINGS survey indicates an interplay of favorable and unfavorable economic factors.

In New England, gray iron production is either up or down depending on whether castings are going to the depressed machine tool industry or the booming textile loom builders. The brass and bronze valve business has fallen off in proportion to the slow-up in new construction. One stabilizing factor is the awarding of 400 contracts for the building of atomic submarines.

In the Montreal area, foundries are operating at about 75 per cent of normal capacity with promise of business picking-up in the spring. An aggressive drive to "Buy Canadian" is aiding in stimulating the nation's industries.

In the British Columbia section foundry activities, as well as business in general, is below normal. However, the pendulum is expected to swing upward during the first half of 1961 with steel and light metal castings leading foundry increases.

At the Purdue Regional attended by foundrymen from Indiana, Michigan, and Illinois, activities were reported down 25 to 35 per cent except for permanent molding. A gradual recovery is expected overall.

Michigan foundries, strongly influenced by the automotive business, reflect two trends. Captive auto foundries are operating at or near capacity. This is normal during the first months of new car production. Consumer acceptance will determine how and who will be operating in the coming months. Independent foundries vary in production, but in general, business is depressed.

Permeating the conferences was the feeling that foundrymen themselves in large measure control the future of the industry. Bruce Simpson, National Engineering Co., Chicago, and former AFS President, typified this tenor. He stated that the industry's problem is not overproduction but underselling. He emphasized that despite increasing competition, metalcasting remains a basic segment of the industrial picture. He called for better organization, regeneration of thinking, and consolidation of efforts.

Summaries of the conferences, except for the Michigan Regional, are below and on the following pages.

Present Extensive Program at Montreal Conference

Most foundries report curtailed production but expect upward trend during spring.

An extensive technical program featuring top metalcasting authorities highlighted the 8th All-Canadian Regional Conference. Sand, iron, casting steel, and non-ferrous topics attracted some 300 foundrymen to the Montreal meeting.

A backdrop was provided by the drive in Canada to "Buy Canadian, to keep Canadians Working." It is hoped that the campaign will assist in bringing foundries back to full working capacity. Another noticeable influence is the St. Lawrence Seaway which is necessitating re-adjustments in the import-export competitive position.

A MODERN CASTINGS spot check at the meeting reveals that foundry business is about 75 per cent of normal with a leveling-off period bringing promise of a pick-up in the spring.

Corrosion and heat-resisting steel casting business seems to be currently booming while other metals are off-pace. Aluminum castings are depressed because of slow household appliance sales. With freight car activity below normal, foundries making bronze journal bearings are pinched. Railroad car wheel casting activities are similarly slow.

Sand Sessions

One afternoon was devoted to sand sessions. Included were:

"Logic in Foundry Sands"—George J. Vingas, Magnet Cove Barium Corp.

"Elevated Temperature Properties—Grain Distribution and Casting Finish"—Victor Rowell, Archer-Daniels-Midland Co.

"Mold and Core Washes"—A. E. Murton, Dept. of Mines & Technical Surveys.

"The Slab Test Block Casting in Sand Control"—George Greiner, Canadian Steel Foundries, Ltd.

"The Determination of True Clay and its Influence on the Quality of Molding Sand"—Desmond R. Phillips, Dominion Engineering Works, Ltd.

"Benefits of Slurry in Foundry Sand"—T. V. Linabury, Miller & Co.

Considerable controversy resulted from criticisms by Vingas on the in-

An Eastern Foundry Conveys and Cools 120 Tons per Hour of Sand with Simplicity "VS" Conveyor

The Simplicity model "VS" conveyor shown moves hot sand from two shakeouts, up a three degree incline, to an elevator at an average rate of 80 tons, with a peak load of one hundred twenty tons per hour. As the sand moves along the conveyor deck, water is added and plows turn the sand thus reducing the sand temperature one hundred degrees. The sand is discharged from the conveyor into the elevator boot over a permanent magnet which removes all of the metal particles.

Simplicity conveyors have proved efficient for transferring materials such as sand and castings, from one point to another. Feed points can be positioned along the length of the conveyor, and materials transferred to a common discharge point.

"VS" conveyors are available in widths from 12" to 36" and in lengths from 10' to 60' with one drive assembly. At customer request, these conveyors can be equipped with liners, covers, or can be built in two surface units.

Write for catalog C-1 which describes the various models of Simplicity Conveyors.

Simplicity
TRADE MARK REGISTERED

ENGINEERING COMPANY • DURAND 1, MICHIGAN

SALES REPRESENTATIVES IN ALL PARTS OF THE U.S.A.
FOR CANADA: Simplicity Materials Handling Limited, Guelph, Ontario.
FOR EXPORT: Brown & Sites, 50 Church Street, New York 7, N. Y.

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adequacy of present sand laboratory tests to indicate how the sand would behave in actual molds and cores. Need for a fresh approach for evaluating sand properties and extrapolating these to production conditions was indicated.

The burden for such an effort would fall on foundry industry suppliers selling sands and binders. Most vendors maintain research laboratory facilities and close liaison with foundries for correlation of results. (See the November issue of MODERN CASTINGS for a complete presentation of these ideas by George Vingas).

It was pointed out that when a sand mix doesn't give a sufficiently smooth surface on the casting it may be preferable to use a wash on mold and core surfaces. Such washes protect the sand from molten metal erosion, sand inclusions, penetration, scabs, blows, and pinholes.

Washes can be custom-mixed to solve particular problems. This calls for the proper blending of liquid, binder, suspension agent, and refractory. The liquid may be water or organic solvent; binders are bentonite, core oil, dextrine, resin, and sodium silicate; suspension agents are bentonite and sodium algonate; refractories include silica, graphite, zircon, mica, powdered coke, and chrome ore.

Too many foundrymen apparently ignore the nature of the fines passing through the 200 mesh screen and consequently run into trouble with green and baked strength mixes.

Use of the hydrometer method will determine the proportion of true clay, silt, and fines. Current practices of using the AFS clay test are inadequate since they do not differentiate between these three entirely different components.

A method to correlate sand laboratory tests with results in the foundry has been developed by Canadian Steel Foundries, Ltd. The "Slab Block Test" evaluates green sand in direct contact with molten metal. This test more nearly simulates actual foundry conditions. The size of the block is varied to correspond with the size of the castings being poured in the sand. It permits custom designing of sand to suit static pressures and configurations involved. It is also used to evaluate materials from different suppliers and to check for variations between batches of materials.

Use of the slurry system for adding binder to sand mixes has several advantages. This technique uses a suspension of binders and water to re-bond old sand mixes. Benefits reported are: up to 50 per cent savings in bentonite; reduced mixing time; less effect by hot sand; less dust at muller; reduced clay-balling; more uniform distribution of binders; more uniform physical properties; less material handling, and labor.

Iron Sessions

An All-Canadian panel of experts presented the cast iron program:

"Self-Service Mixing Ladle at Cupola"—Andre Cecil, Warden King Div., Crane Piping, Ltd.

"The Effects of Chilling on Cast Iron"—J. E. Rehder, Canada Iron Foundries, Ltd.

"Cast Iron Melting Furnaces in Canada and Future Trends"—Frank W. Kellam, Electro Metallurgical Co.

"Some Controls, Some Properties, Some Production Techniques of Ductile Cast Iron"—P. J. Provias, International Nickel Co. of Canada, Ltd.

Elimination of much hand labor was achieved at Warden King, Ltd., by mechanizing the tilting of the receiving or mixing ladle in front of the cupola. The ladle can be tilted at a constant rate when filling-pouring ladles. Limit switches permit automatic return of the receiver to the level position when the pour-off man has his metal. The push-button operated 1-1/2 hp motor also tips the ladle backwards when slag must be skimmed. Operations are now safer, faster, and less laborious.

Tips on how to increase chilling in gray iron were presented by speaker Rehder. Possibilities are: placing metal or graphite chills in molds; melting in an atmosphere high in water vapor; holding molten iron a long time at high-temperature; decreasing silicon and carbon content of alloy; raising phosphorous content; adding chromium or vanadium; inoculating with tellurium, boron or bismuth.

The chilling tendency can be decreased by reversing the above practices as well as by: using insulating materials in mold; keeping moisture, clay content, and fines low in sand mixture; avoid putting white iron in the furnace charge; minimizing steel and iron scrap in charge; and inoculating with ferrosilicon, calcium silicon, or graphite.

According to F. W. Kellam, Canadian foundries are now operating 266 cupolas which include 4 balanced blast, 3 hot blast, 15 water-cooled, and 8 basic. The newest trend is toward use of a carbon well in the cupola. Bottoms don't have to be dropped nightly; banking is done with the coke charge. A modern cupola is ideally equipped with hot blast, water-cooling, basic lining, and carbon well.

P. J. Provias gave a run-down on ductile Iron (the segment of the metalcasting industry showing the greatest growth). It is imperative to get the sulfur below 0.04 per cent before adding about 0.04 magnesium in a carrier-type alloy such as Ni Mg Si. A close check on metal quality must be maintained in the melting department. Tests include chill and keel block, hardness, and rapid microscope examination.

Melting and welding were emphasized at the steel session. Talks were:

"Welding as Applied to Foundries"—C. R. Whittemore, Deloro Smelting & Refining Co., Ltd.

"Construction Problems of Large Pattern Equipment"—A. E. Wells, Dominion Engineering Works, Ltd.

"Direct-Arc Steel Melting in the Foundry"—M. Colman, Canadian Steel Foundries, Ltd.

"Foundry Welding and the Electrode Influence"—C. Sebistianowich, Dominion Engineering Works, Ltd.

A complete metallurgical understanding of the effects of elements and temperature are essential to proper welding techniques. A weld

All-Canadian Conference officials go over last minute details. Left to right: A. K. Durrell, Dominion Engineering Works, Ltd.; Max Reading, Foundry Services (Canada), Ltd.; W. Tibbitts, Canadian Steel Foundries, Ltd.; and M. Trottier, Quebec Iron & Titanium Corp.

deposit is just a casting made on top of a base casting, acting as a chill on the solidifying metal. Welding in foundries may be used for joining castings, repairing, hardfacing selected surfaces, and maintenance.

Melting practices for producing low sulphur steel continues to interest steelmakers. One approach to removing sulphur is through oxidizing slags, according to slagging technology.

Non-Ferrous Sessions

J. G. Dick, Canadian Bronze Co., Ltd., discussed "Selection and Application of Copper-Base Alloys in Industry." He emphasized how misapplications jeopardize the reputation of the entire copper-base industry. Too often, copper-base alloys are indiscriminately used for their corrosion resistance.

Foundrymen and designers often fail to realize that certain corrosive media are completely incompatible with some copper-base alloys. "To the extent to which a greater degree of cooperation and solicitation of advice can be established between the designer and the foundry, to this extent will poor selection and misapplication of alloys be eliminated."

"Some Recent Developments in the Metallurgy of Aluminum Foundry Alloys," were related by C. J. Zabek, Aluminum Co. of Canada, Ltd. He emphasized the new competitiveness of permanent mold castings through development of new high purity Al-Si-Mg alloys. Alloys can be heat treated to develop high strengths and improved ductility by keeping iron contamination low.

D. A. Dodson, Foundry Services (Canada), Ltd., explained the causes and cures of casting defects. Some defects causes include: excessive moisture in mold or ladle; metal turbulence on entering the mold; pouring too cold; inadequate mold and core venting; mold-metal reactions; gases dissolved in molten metal; poor feeding of liquid shrinkage; bad casting design; inclusions; soft ramming; and improper sand mix. The difficulty is to recognize the defect and its cause. Once diagnosed, relatively simple cures are available.

The technical program was supplemented by plant tours. Included were: Canadian Steel Foundries Ltd., the largest steel foundry in Canada; Canadian Steel Wheel, Ltd., a completely automated steel wheel forge shop; Dominion Engineering Works, Ltd., the largest integrated group of Canadian foundries having steel, iron, and brass foundries; Montreal Bronze, Ltd., a leading non-ferrous jobbing shop; Warden King, Ltd., a high production iron foundry; and Jenkins Bros., Ltd., producer of bronze and iron valves.

Max Reading, Foundry Services (Canada), Ltd., was conference chairman. A. K. Durrell, Dominion Engineering Works, Ltd., W. Tibbitts, Canadian Steel Foundries, Ltd., and M. Trottier, Quebec Iron & Titanium Corp., were co-chairmen.

Modern Methods, Technology Focus at New England

Foundry production varies greatly, atomic submarine contracts add stabilizing effect.

The 20th New England Regional Foundry Conference at Boston was dedicated to bringing some 300 conferees to close grips with today's most modern methods and technology. A carefully diversified agenda included something for everyone—ductile iron production techniques, metallurgy of aluminum bronzes, new binders for cores and molds, equipment designed for every foundry need, epoxy resin patterns, selling castings, and foreign foundry developments.

Business conditions in New England are fairly good. This was indicated by a spot-check made by MODERN CASTINGS at the sessions.

Machine tool sales have been slow now for most of 1960. But an improved order picture is indicated. New England foundry business is tied closely to machine tool building and textile machinery manufacturing.

Loom builders have had an unusually good year because of a new loom design that is sparking extensive modernization. Obsolete looms are being replaced. Add to this a boom in soft goods sales and you have a steady demand for castings needed to build new equipment and to maintain the old.

Brass and bronze casting demands in New England depend on several influences. For instance, the valve business leans heavily on commercial building, industrial plant construction, ship building, and the chemical industry. A strike of pipe fitters slowed up the valve casting business but activity is now picking up.

Four hundred contracts for building atomic submarines are scattered around New England and help stabilize metalcasting demands at a time when other business activity is slow.

Inventories of raw materials at most foundries are thoroughly depleted. So pig iron and ingot sales now more accurately reflect melting activity. Foundries are minimizing inventory investments. This means a steady hand-to-mouth purchasing of supplies instead of the complete drouth of purchases when foundries were living off inventories.

Foundry sand sales have been good in New England. Credit is given the new process such as shell, CO_2, air-set, etc. which require good quality, graded, washed and dried silica sand. In most of these processes the sand is not re-used so a steady supply of new sand must be purchased.

At the sessions, selection of proper equipment suited to the particular production needs of each foundry was covered by O. H. Kastens, Newago Engineering Co., Newago, Mich., George Koren, Beardsley & Piper Co., Chicago, and L. G. Probst, National Engineering Co., Chicago.

The New England foundry industry comprises some 491 foundries —164 pour gray iron; 270 have less than 20 employees. Recently foundry equipment manufacturers have been giving considerable attention to meeting the needs of small foundries, which dominate the metalcasting picture. Equipment has been miniaturized and "economized."

New sand technologies—CO_2 process shell mold and core making, air-set, hot core-box—have put a heavy responsibility on manufacturers to build equipment for sand preparation, material handling, molding, core-making, and reclamation. Now

a variety of designs suit all sizes and eccentricities of operations.

Most equipment can be amortized in at least three years, often sooner. This means foundries can afford to modernize and stay competitive. Foundries and equipment manufacturers have traditionally worked together in meeting needs peculiar to individual plant operations.

Foreign Foundry Influences

The international flavor was brought to the program by Lester B. Knight, Lester B. Knight & Associates, Chicago; and Lawrence J. Litalien, Waterbury Farrell Foundry & Machine Div., The Textron Co., Waterbury, Conn.

Knight related his observations of European foundries, which he had just visited. American dollars, technical assistance, and equipment are helping European foundries become tough competition. Modern European soil pipe foundries can now market pipe in the States.

European metallurgy and melting equipment leads U. S. practices. A serious lack of quality raw materials has been compensated for by ingenious metallurgy. European foundries produce a great variety of alloys using complex cupola designs, arc furnaces, and induction units. All major foundries have large research departments planning tomorrow's technology.

Low tooling costs for patterns is resulting in some pattern building in Europe and shipped to U. S., resulting in a 35 per cent saving.

European governments are helping to strengthen their industries through tax relief and labor negotiation assistance. Business is so good that most foundries have a two-year backlog of orders.

Litalien described an entirely different industrial picture in Latin America. These countries are definitely struggling to become industrialized. They seek technical assistance from the United States and have only an embryo foundry industry. With a population well over 200 million, Latin America represents a lucrative export market for machinery and equipment built with castings. So foundries stand to benefit in proportion to the growth of trade with Latin America.

Ductile iron casting production developments were reported by Arthur Avedesian, Taylor & Fenn Co., Windsor, Conn.; Lewis Greenslade, Jr., Browne & Sharpe Mfg. Co., Providence, R. I.; Frank Harness, Ductile Iron Foundry, Inc., Stratford, Conn.; and Andrew Jenckes, J. S. White Co., Pawtucket, R. I.

It was felt that New England foundries were behind the rest of the country in ductile iron production. More effort needs to be made to acquaint design engineers with its properties so ductile iron will be specified more often.

Applied Technology for Profit

Several speakers favored the use of the small 1000 pound reverberatory-type furnace for melting relatively small batches of metal at a time. Metallurgy is easier to control in it than with a cupola. Also, it enables operators to gain experience, with small batches of metal.

If production needs increase then the basic-lined, water-cooled hot-blast cupola becomes the ideal melting unit for producting low-sulphur base iron for conversion to ductile.

Brass and bronze foundrymen were given new hope by N. A. Birch, National Bearing Div., American Brake Shoe Co., Meadville, Pa. Emphasizing opportunities created by the development of new aluminum bronze alloys, Birch cited extreme versatility, high strength and toughness, ductility, hardness and corrosion resistance of the alloy. These properties make aluminum bronzes suited for bearings, brackets, cranks, pins, levers, wheels, pumps, impellers, pipes, valves, fittings, and propellers.

He predicted a steady growth in use of aluminum bronzes, especially as the design engineers recognize their potential.

"Epoxy Resins in Patterns for Jobbing Foundry" was covered by Robert Scott, Canadian General Electric Co., Toronto. He demonstrated the versatility of the epoxy plastics for solving pattern rigging problems.

Latest developments in binders for cores and molds were handled by Victor Rowell, Archer-Daniels-Midland Co., Cleveland. He discussed the new furfural binders for use in hot core box production. This process looks very competitive with shell molding. Furan-resin bonded sand is blown into a metal core box heated to 400-600 F. Within seconds the heat starts acid catalyst reacting with the binder and almost instantly hardens the core. About 14 foundries are currently evaluating the process and several large ones are already in production. Management and technicians should take a close look at this new binder to see if it fits into their operations.

"Selling Castings in a Buyers' Market" was highlighted by the concluding speaker, Everett E. Norton, Norton Associates, Rockland, Conn. He stressed the importance of knowing costs to judiciously set prices for castings so that orders will bring a profit.

He advised the group that metal-casting management should know what type of work, the size, and quantity of castings they can best handle. Stay within these brackets, he warned, and don't be afraid to turn down an order when it falls outside the realm of your operation.

Committee officers in charge of the conference were: Chairman A. Erkkinen, Fremont Casting Co., Worcester, Mass.; Vice Chairman Philip C. Smith, General Electric Co., Lynn, Mass.; Publicity Chairman John H. Orrok, Debevoise-Anderson Co., Boston; and Treasurer Herbert H. Klein, Klein-Farris Co., Boston.

The two-day session was held in Kresge Auditorium, M.I.T., Cambridge, Mass., a tradition of many years. Gordon Brown, M.I.T. Dean of Engineering, welcomed the visiting foundrymen to the campus. AFS Director Robert R. Ashley welcomed the group on behalf of the National Office.

New England Conference officials studying regional program. Left to right: Vice-Chairman, P. C. Smith, General Electric Co.; Treasurer, Herbert H. Klein, Klein-Farris Co.; Chairman, Ahti Erkkinen, Fremont Casting Co.; and Publicity, John Orrok, Deveboise-Anderson Co.

Operating Problems, Costs Emphasized at Purdue

Operations below normal but gradual recovery predicted for all phases of industry

Operating problems and cost cutting rather than basic research, held the spotlight at the Purdue Metals Castings Congress conducted at Purdue University, Lafayette, Ind.

This emphasis prevailed whether the subject was cupola operation, melting, or gating and risering. Speakers at the many sessions stressed that quality is built into castings through close details, adherence to fundamentals, and better trained personnel.

The conference was held against a background of curtailed foundry operations. Business in some areas of the region is down approximately 35 per cent from peak performance. Some reports are that the non-ferrous industry is running at a slightly higher rate than the ferrous industry.

The exception appears to be in the permanent molding field where a large portion of the work is in defense projects which are cushioned with considerable lead time. Reports on activity in this area varied from city to city but in general the most optimistic reports were from spotty to fair.

Despite the reduced production, operators, here, are not discouraged. Although none could see bright spots in the immediate future, all felt that recovery would be gradual and with increased competition from other means of fabrication.

Foreign competition does not appear to be a threatening feature. The decline in business is attributed to the national industrial slowdown.

Metalcasters were challenged to improve quality control programs and to change their attitude toward quality by H. S. Kindle, manager of quality control, Cummins Engine Co., Columbus, Ind.

He told of Cummins' annual casting purchase of $20,000,000 for 18,000 to 20,000 tons of castings. The firm expects to lose $140,000 in direct costs for machining defective castings in 1960. Defective castings returned to foundries are estimated at $857,000 for this year. These figures do not include disruption of Cummins' schedules or the cost of handling, shipping, and internal scrap charges to foundries.

Kindle observed that a considerable amount of quality control equipment could be purchased for a fraction of the amount of money represented by returned castings. This equipment in addition to reducing costs would put foundries in a better competitive position with other forms of fabrication.

The future facing foundrymen was summarized by Ray Cochran, R. Lavin & Sons, Chicago, who said, "Casting to rough size remains the only sensible way to produce many of the complex shaped metal parts required in modern engineering. As a result it becomes increasingly necessary to produce castings having physical and mechanical properties competitive with those of forgings, weldments and other wrought forms."

Quality Control Stressed

Cochran stressed the importance of quality control in his talk on melting copper base alloys, stating that some practical method of measuring melt quality must be devised and used. Measuring melt qualities in the laboratory, free from pressures of production requirements, is easy. Quality can be determined on the basis of density, mechanical strength, or from a metallographic section. Such methods, however, are useless as production control measures.

The linking of fundamental research, laboratory procedures, and production was echoed by R. W. Ruddle, Foundry Services, Inc., Cleveland. He emphasized that relatively small attempts had been made to utilize data on the mechanism of freezing rates developed during the past 15 years. What is needed is a means of determining the causes of freezing, translated into a practical method of determining casting quality. Although prospects for this lie in considerably more research, alert foundrymen today will incorporate present knowledge of heat flow in castings and molds.

Buying on price, whether by casting customers or by foundries, can result in higher actual costs, warned Robert Greenlee, Auto Specialties Mfg. Co., St. Joseph, Mich. A plan there, now in its fourth year, is saving considerably on scrap melting costs, despite a higher initial price. Scrap is divided into four categories based on section thickness and melting costs determined by production runs. Based on this, hydraulically-pressed bundles from selected sources entailing a premium, proved to be the most economical purchase.

Attention to other operating details also pays dividends, said Greenlee, citing such examples as careful humidity control in the cupola, exact measuring of bed height, and thorough analysis of incoming materials.

More than 50 per cent of bad aluminum castings can be traced to poor pouring practices, stated R. A. Colton, American Smelting & Refining Co., Houston, Texas. Aluminum by nature is subject to considerable turbulence and careful control must be exercised to produce quality castings.

Colton traced some of the aluminum pouring practices to use of ferrous pouring practices. These include excessive pouring height, location of sprue in center of flask, and use of large circular sprues. To minimize turbulence he advocated chokes, tapered rectangular sprues, location of sprue at the end of the flask, and a minimum pouring height.

How foundrymen can aid designers in producing better castings was outlined by John Leath, Harrison

Purdue Metals Castings Conference officials: program chairman, T. E. Smith, Central Foundry Div., GMC., Danville, Ill.; chairman, H. B. Vorhees, Mishawaka, Ind.; assistant program chairman, J. C. Maggart, Sibley Machine & Foundry Corp., South Bend, Ind.

Steel Casting Co., Attica, Ind. "We must do everything in our power to assist the designer in producing a part that will give the best performance, being alert to foundry defects that cause stress concentrations and poor results on application," he stated.

Four areas were studied by Leath. Casting design, proper pattern construction and rigging, careful study of each job to eliminate internal shrinkage and hot tears, and careful, planned workmanship at all stages of production.

Manufacturing of leaded steel castings for improved machinability was discussed by George P. Dahm, Linde Co., Cincinnati; H. J. Weber, AFS Director of Safety, Hygiene and Air Pollution Control; and Russell Plum, Keokuk Steel Casting Co., Keokuk.

Dahm described compressed air equipment used for injecting lead into molten steel. Weber stressed health hazards of lead and its compounds, stating that in machining operations there is probably no health hazard if the cutting tool produces chips and shavings. In grinding and welding operations fine dust and fume may produce health hazards. During inoculation of the steel, there is definitely a health hazard because of the lead fume, necessitating control measures.

The relationship of microstructure to the mechanical properties of gray iron was discussed by S. C. Massari, AFS Technical Director. The mechanical properties of the various microconstituents found in gray iron were covered, together with their charcteristic structure.

It was emphasized that the properties of any iron are wholly dependent upon the particular constituents present and their relative amounts. The properties of gray iron are the result of these constituents and not upon its chemical analysis. The chemistry of the iron is only an aid to achieving the desired structure and mechanical properties in iron to meet the specific needs for a given application.

Preventive maintenance was discussed by a three-man panel consisting of Glen Snellenberger, Dalton Foundry Co., Warsaw, Ind.; John A. Shelby, International Harvester Co., Indianapolis; and Robert Clark, Golden Foundry Co., Columbus, Ind.

Careful study of the shell core process must be made before adopting the process, advised M. H. Horton, Deere & Co., Moline, Ill. Horton enumerated several problems encountered at Deere & Co., and how they were solved.

The conference was sponsored by the AFS Central Indiana and Michiana Chapters in cooperation with Purdue University.

H. B. Vorhees, manufacturers' agent, Mishawaka, Ind., was conference chairman. Thomas E. Smith, plant manager, Central Foundry Div., Danville, Ill., was program chairman.

Foundrymen Reply to Criticism on Quality Control Voiced at Purdue Conference

Strong criticism of existing foundry control methods was voiced by H. S. Kindle, Cummins Engine Co., Columbus, Ind., at the recent Purdue Metals Castings Conference. The talk brought strong reaction from key foundry executives contacted by MODERN CASTINGS. His statement that no foundry to his knowledge, had adequate quality control methods was particularly challenged.

Kindle, manager of quality control, advocated a closer liaison between foundries and customers. He listed a nine-point control program which he maintained could be adopted without excessive burden by foundries.

His program included:

1. Sectioning the first piece of all new castings to assure conformance to customer blueprint requirements before submitting the first sample to the customer. Early samples should also be used to check on internal soundness.

2. Establish controls to see that the best gating and risering methods are adopted as rapidly as possible.

3. Good laboratory controls of sand mixtures and attributes of metals such as chemistry, microstructure, and hardness.

4. Carefully planned inspection of production castings for cleanliness, finish, evidence of cracks, handling damage, and other visible defects.

5. Dimensional checking of production castings by gages and fixtures.

6. Periodic sectioning of castings in known trouble areas to check for porosity and other internal defects.

7. Perform non-destructive tests such as x-ray, gamma ray, ultrasonic, and others.

8. Periodic examination of castings and patterns for evidence of wear, core shift etc. to determine if pattern repairs are necessary.

9. Periodic check of gages and other measuring equipment to assure continued accuracy.

Typical reactions are:

"Disagree with statement that no foundry within his knowledge is using adequate control. Many foundries have made much progress using these techniques."

"He tars all foundries with the same brush and we feel that he is not justified. Where there is a sincere interest of responsible personnel to buy quality instead of only price, many of the objections raised by Mr. Kindle are of a minimum."

"Gating and risering we think are foundry's responsibility. All these things create special operations, the cost of which must be included in pricing. This point is apparently not clearly understood by many customers."

"It would be wonderful if foundries could get a high enough price for castings to afford all that he asks. Probably in the over-all picture, the total cost figuring the savings in the machineshop, freight savings, etc., would even out. At present levels with the purchasing department attitude in many companies at the present time this would be impossible. Perhaps we need a thorough education of buyers, salesmen, and the foundries."

"We feel that he is justified in asking for the best, and we in turn, want to supply the best. In their inspection standard, Visual Inspection of Unmachined Castings, they list one, and only one reference, the AFS ANALYSIS OF CASTINGS DEFECTS. How can we argue with that?

"It is highly important that proper instructions be given to the foundry as to the function of the casting in the final product. We find much of the equipment coming to us disagreeing with the blueprint. Many are not engineered for economical casting due to a lack of coordination between the metalcasting customer and the foundry."

"As soon as standards are met, they are raised again. It becomes a matter of whether or not the customer wants to pay the price of foundries constantly meeting these increasingly high standards."

Modernization, Mechanization Stressed at Vancouver

Predict area business recovery during 1961 paced by steel and light metals castings

Modernization, research, and aggressive merchandising are keys to the future of the foundry industry, Canadian and U. S. foundrymen were told at the recent Northwestern Regional Foundry Conference held in Vancouver, British Columbia.

The program, designed for this section, drew heavily from Canadian metalcasting experts. Emphasis was placed on operating problems and techniques. Topics of interest to major segments of the industry were included. The program was supplemented by a visit to the aluminum extrusion works of Aluminum Co. of Canada, Ltd., Vancouver.

Foundry business, and business in general is reported slow. Some upturn is predicted in the first or second quarter of the coming year, particularly in light metals and steel castings.

Throughout 1960, business has been fair to depressed. New construction work is limited and both the mining and lumber industries are in a low period. Local foundries also suffer from some importing of castings from the United States, Europe, and Japan.

Foundries contacted by MODERN CASTINGS as to local business conditions indicate that foundries are constructing new plants, adding or enlarging departments, and modernizing existing facilities. Cleaning, molding, and sand handling operations in particular are receiving attention.

Challenge to Foundries

In an analysis of the present and future of the industry by AFS Technical Director S. C. Massari, management was warned that casting quality must be improved and new applications found to remain competitive.

Massari pointed out that although considerable progress has been made in the past 20 years, it must be greatly accelerated if foundries are to meet the technological advancements in other fields.

He pointed out "The needs of a rapidly changing technological area are crowding hard upon the physical and chemical limitations set by available engineering materials. In every area of advancement, new construction designs, more powerful engines and machines, high temperature processes and reactions, nuclear science and engineering as well as the aircraft and missile field, demand very high performance in the material involved."

How can foundries improve their competitive position? Massari recommended improved foundry processes, better quality control, closer dimensional reproducibility, and improved casting finish. This, he observed, can be accomplished through research and development.

Resins Stir Interest

Considerable interest was shown in the use of synthetic resins for foundry use. E. Wenninga, Waldor Enterprises, Ltd., Montreal, outlined their advantages and application techniques.

Advantages claimed for these resins which have been used for the past six years in Canada for producing foundry equipment are:

Simplicity of manufacture. The initial investments required to set-up a plastic tooling department need not exceed $250. Also, master wood patterns may be made allowing for single shrinkage only.

High wear resistance. Epoxies have proven to be more wear resistant than equivalent metal pattern or core box equipment.

Reduced maintenance costs. Repair of worn areas may be effected quickly without high labor costs or delays. Dimensional changes may be made without trouble.

Easy sand release. Plastic tools are released from sand with greater ease than metal tools and it is often possible to eliminate loose pieces. Core can be molded with minimum draft.

Lighter weight. Plastic tools weigh less than the metal counterparts with less material handling problems.

Longer storage life. Cured resins are unaffected by humidity, various weather conditions, or normal corrosive conditions.

Lower costs. Cost figures vary from 10 per cent to 100 per cent of the metal tooling depending upon the intricacies. These costs are not so readily ascertained as those resulting from better sand release, elimination of loose pieces, easier handling, and other factors reflected by lower overall production costs.

The conversion to ductile iron of mechanical and hydraulic winch drums previously manufactured entirely from steel, was told by R. B. McDonell, McDonell Metal Mfg. Co. The paper co-authored by Aubrey S. Tuttle, International Nickel Research & Technical Services, Ltd., told of the manufacturing methods which give significant production savings and certain engineering property advantages.

Aluminum matchplates and loose patterns are used in molding. Some cores are being hardened by CO_2 and others baked in a natural gas-fired, car-type furnace. The largest castings are molded in ductile iron hinged boxes using a synthetic green sand. Aluminum flasks are used on some small castings.

Jot-squeeze and air ramming is used, depending upon size and complexity of the casting. Gating is provided on some patterns while others require hand-cutting.

Highlights of the foundry program at Vancouver Technical High School were given by W. C. Catherall. Emphasis was placed on the after hours of off-the-job training program, started three years ago. Each apprentice receives his instruction free with the course pattern laid out by AFS members.

Other speakers on the program were G. Harris, Anthes-Imperial Co., Ltd., who spoke on "Use of Calcium as a Desulphurizer in an Acid-Lined Cupola;" Paul H. Hookings, Granby Consolidated Mining, Smelting & Power Co., "Heat Treatment of Aluminum Alloys;" J. B. Hopkinson, North Shore Foundry, Ltd., "Five Thousand Years of Progress in Bronze Castings;" J. B. Belyea, Vancouver Steel Co., Ltd., with paper presented by John Billings, "Steelmaking in Hawaii;" F. M. Kellam, Alloys & Electrodes, Union Carbide Canada, Ltd., "Cast Iron Melting Furnaces in Canada and Future Trends;" Dr. R. H. Wright, University of British Columbia, "Something About Research;" W. B. Johnson, Aluminum Co. of Canada, "This Wonderful World."

The conference held at the Hotel Georgia, was sponsored by the AFS British Columbia, Oregon, and Washington Chapters and the Oregon State University Student Chapter.

Herb Heaton, Mainland Foundry Co., Ltd., Vancouver, was the conference chairman.

CHAPTER NEWS

TEXAS—Members examine a complete set of AFS books and literature. Many chapters display AFS books at each meeting to stimulate their educational programs. Texas Chapter E. Eugene Silver reports that sales were brisk at this recent meeting.

CENTRAL INDIANA—Relaxing for a moment are Wayne Seay, retired; Lou Essex, Golden Foundries Co., Columbus, Ind.; Emil Schmidt, Fanner Chaplet Co., Cleveland; Anthony Downey, International Harvester Co., Indianapolis; Bud Ostermann and Tom Blanton, International Harvester Co., Indianapolis—by William R. Patrick.

UNIVERSITY OF ILLINOIS—Student Chapter Officers, left to right: President, Dennis G. Peterson; treasurer, John W. Dorfmeister; secretary, Henry S. Miller. Approximately 100 persons attended the opening session at which a discussion of foundry problems and solutions was presented by Jim Benford, Walter Zott, and Bob Robinson, of Central Foundry Div., General Motors Corp., Danville, Ill. —by Charles M. Phipps, Jr.

TENNESSEE — Chairman Thomas A. Deakins, Marshall T. H. Stewart, and Secretary Samuel F. Torbett with prize awarded at the chapter's outing.—by John D. Kling

AFS Publishes New Chapter Directory

Officers and directors of the Society's 47 chapters in the United States, Canada, and Mexico are contained in the recently published 1960-61 chapter officers directory.

Also included is a location map of AFS headquarters, a list of the AFS 1960-61 Board of Directors, AFS regions, chapter contact assignments, chapter meeting dates and locations, and major AFS events.

Quad City Chapter

What's New in Metalcasting

Major interest areas of foundrymen were covered by Jack H. Schaum, Editor, MODERN CASTINGS, in a talk entitled "What's New in Metalcasting." Most new advances in the industry stem from foundrymen dedicated to staying constantly competitive in quality and price by making the casting process the shortest and fastest and straightest line between raw material and finished product.

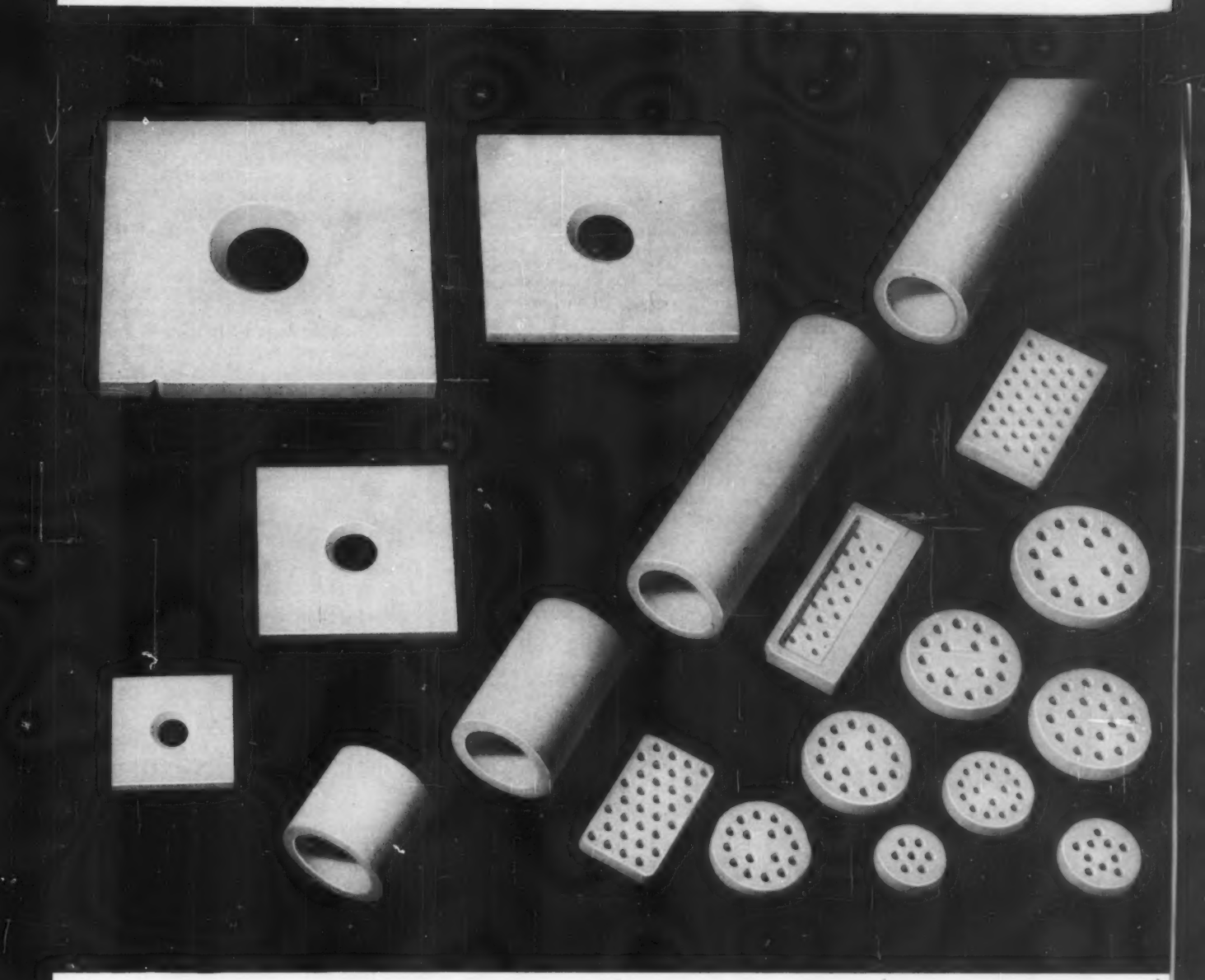
For example: Certain cast iron pipe plants are shipping finished pipe—steel hot—one hour after the scrap metal was charged into the cupola. Hot metal die casting plants have been built adjacent to aluminum smelters so molten metal can be delivered directly to the foundry without pigging and remelting. Iron ore can now be mixed with powered coal or coke and reduced directly to molten iron without need for blast furnace. Elimination of pig iron and scrap metal melting contribute a significant economy to iron and steel foundry operations.

Schaum also described such recent significant technological breakthroughs as: lost pattern process, fugitive disposable patterns, nickel carbonyl patterns, nuclear moisture gage for green sand, zircon shell molding for steel casting, hot core box process, vacuum venting, and casting the impossible.

Piedmont Chapter

Foundry Profit & Loss

Profits and losses in foundries were discussed at the opening meeting by Jeff Westover, Westover Corp., Milwaukee. He spoke on standard costs, yield, melt costs, job breakdowns and explained the use of break-even charts. Three departments needing constant attention were cited, industrial engineering, order follow-up, and maintenance.—by Larson E. Wile



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Louthan Strainer Cores are now available in more sizes and shapes—and for *steel, iron, brass* and *bronze* castings. All provide an accurate choke for positive control of metal flow, eliminate slag and oxide inclusions.

Louthan Breaker Cores facilitate rapid removal of the riser with subsequent labor savings. There is no core gas. You get cleaner castings. Available for all riser diameters from 2″ to 12″, and for use with *any metal casting* risering from a flat surface.

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ST. LOUIS—H. J. Weber, left, AFS Director of Safety, Hygiene and Air Pollution Control, discusses his talk with R. E. Miller, Great Lakes Carbon Co., technical chairman. Weber pointed out that the AFS Central Office will assist chapters in air pollution problems. He outlined various dust collecting equipment and their approximate costs.—by W. E. Fecht

CENTRAL OHIO—Chapter Chairman N. V. Stapf congratulates J. A. Gitzen, left, Delta Oil Products Corp., Milwaukee, who spoke on chemical and physical properties of mold and core sand additives.—by Joseph A. Riley, Jr.

ONTARIO—Shell cores, shell molding and resin coated sands were discussed by H. von Wolff, Shalco Div., National Acme Co., left, and F. W. Less, Durez Plastics Div., Hooker Chemical Corp.—by E. J. Skelly.

Central New York Chapter

Foundry Quality Control

Regardless of size, any foundry will greatly benefit from quality control, Prof. J. V. McKenna, Syracuse University, told members. The value of AFS books was explained by Burdette Harris, Harris Pattern Works, Inc., Liverpool, N. Y.—by Anthony Izzo

Twin City Chapter

Veining and Penetration

Veining, according to Geo. DiSylvestro is an irregular, thin film of metal protruding from a casting surface where the mold or core has cracked and allowed metal to enter this fissure. At the casting temperature, the sand expands and may crack to give rise to an irregular surface or veining.

DiSylvestro, American Colloid Co., Skokie, Ill., explored various phases of this defect at a recent meeting. He stated that adequate venting was considered essential because it is a means of eliminating both excessive heat and gas that is liberated from a decomposing binder.

He noted that veining is markedly reduced if the sand can be made quite plastic at the metal pouring temperature or several hundred degrees below. He cited the addition of iron oxide as one method used to achieve this. Certain iron oxide compounds, with controlled amounts of impurities added to the core mix will develop this plasticity quite readily.

Iron oxide of the Fe_2O_3 type gives the required degree of plasticity and performs well; whereas, Fe_3O_4 type performs very poorly. Iron oxide that performs well melts at the casting temperature producing a uniform and plastic core surface. Certain bank sands possess broad plastic ranges and rarely cause veining.

To produce higher quality castings DiSylvestro recommended: have equipment to test raw materials used in mold and coremaking and develop specifications, and purchase binders and additive that are designed for the job.—Matt Granlund

Rochester Chapter

Using Exothermic Materials

Advantages of moldable exothermics for ferrous and non-ferrous foundries were explained by Douglas Beath, Foundry Services Co., Cleveland.

Moldable exothermics can be used most effectively on solid front solidification alloys such as steel, ductile iron, high alloy irons, bronzes, and aluminum alloys. For these, the most practical riser dimension to use is that of height equals diameter. This gives maximum volume with minimum surface area.

Long range solidification alloys such as gray iron, require additional metal pressure to force molten metal between dendrites requiring a height of 2 to 2-1/2 times that for the riser.

Figures comparing the time metal remained molten in risers were given. A top shield increases the molten time by 50 per cent over an open riser. A riser with an exothermic sleeve and top shield remains molten four times as long as a riser without sleeve and shield.

Moldable exothermic sleeves can be made by jolting, squeezing, blowing or hand ramming.

Exothermic materials are of four types: highly exothermic, moldable exothermics, hot tops, and insulators. All exothermic materials involve the chemical reaction $2AL + 3\ FeO = AL_2O_3 + 3Fe + \text{heat}$.

The physical properties of sand containing moldable exothermics are:

Green strength	8-10 psi
Dry compression	650-1200
Dry strength	100-400
Temp. attained	3200 F.
Heat properties	1800 F./lb.

Advantages of moldable exothermics were listed as: 60-70 per cent less metal in risers; A liquid reservoir is available to eliminate shrinkage cavity throughout solidification provided correct thermal gradients are set up; Chipping time reduced due to less cut off time; Less metal poured; Increase in yield of 60 to 90 per cent of metal melted.

It was stated that if melting costs are greater than 1-1/2 cents per pound, it is economical to use moldable exothermics to increase pouring yields.—by Haerle Wesgate.

Ontario Chapter

Shell and Resin Techniques

Use of shell core and shell molding resin coated sands were explained by H. von Wolff, Shalco Div., National Acme Co., Cleveland, and F. W. Less, Durez Plastics Div., Hooker Chemical Corp.

Shell cores, said von Wolff, may be applied in any foundry. They reportedly give better tolerances, finer finish, and lower costs. Cost reductions may be achieved through faster production, use of unskilled labor, elimination of tooling and drying, core washes, ovens, plus a saving in floor space.

Use of a carbon additive cuts down on metal penetration. It serves as a cushioning agent and prevents metal penetration due to the expansion characteristics of silica sand. Other cushioning agents are iron oxide and clay.

In dealing with coated sands, Less said that a resin, either liquid or dry, is added with "wax" or metallic soap to the muller. With a dry resin, a solvent must be added to carry the

resin to the sand particles. A further development is the one-step or two-step phase.

In the former, all ingredients are mixed prior to addition to the muller. In the latter, a catalyst in the form of a formaldehyde compound is added to the muller to control the rate of reaction of the various compounds. It is possible to vary the hot and cold strengths of the sand according to the percentage of the formaldehyde added.

The important factors affecting the type of bonding of the sand are muller time, uniformity of particle size, sand temperature, balling, abrasion, air impingement, drying, curing time, curing temperature, and gas evolution.—by Arnold Pletzer and Paul B. Walters

Wisconsin Chapter

Discusses Furfural Binders

Simultaneous sessions in malleable, gray iron, pattern, and steel opened the chapter's technical year.

High-speed, low-cost furfural binders hold a promising future, Wayne H. Buell, Aristo Corp., told malleable foundrymen. The new binder is made by combining furfural alcohol and a formaldehyde.

In coating with the binder, the resin and catalysts are added to sand in a 5:1 ratio. It is thoroughly mixed in as short a time as possible. The mixed sand has a very low green strength and is easily blown into a core box. The normal core box temperature of 400 F. produces a core in 10 to 20 seconds, depending upon its section thickness. The blow plate must remain at normal temperature to prevent activating the binder in the sand remaining in blow holes.

Furfural binders are used in making shell cores where the thickness does not exceed one inch. Thicker section cores must be hollowed with taper plugs or lighteners contoured to the inner core surface. Due to its high speed, it is excellent for high production types of cores.

R. A. Clark, Union Carbide Metals Co., Div. Union Carbide Corp., Cleveland, discussed ferroalloys for the foundry industry. Particular emphasis was placed on economics of the melting operation. Clark related the source of silicon, such as silvery pig, pig iron, silicon briquetts, and lump ferrosilicon, to other materials used to make the cupola charge. The complete charge make-up in turn was related to the individual current market prices of the materials used.

Marshall Eckbald, Wisconsin Pattern Works, Racine, Wis., urged a revitalized selling and development program by the pattern industry. He said that in the past industry had told patternmakers what it wanted, now patternmakers should tell industry what it can do for them. New fields are the expanding areas of die casting and permanent molding.

Wayne Wilcox, Arcair Corp., outlined the repair welding of carbon and alloy steel castings. Among topics covered were submerged arc welding, treatment of castings after welding, and the electro slag process.—by R. B. Ballmann

Central Illinois Chapter

Urea-Furfural Alcohol Binders

Development of urea-formaldehyde resins for the foundry industry were discussed by John Albanese, Acme Resin Co. He outlined advantages and limitations of the resins.

Tom Cody, International Harvester Co., Canton Works, past director of the chapter, was presented with a certificate in appreciation for his efforts to the chapter and the industry in general. Cody is retiring.—by Charles W. Search

Pittsburgh Chapter

Benefits from AFS

Benefits to be derived from active participation in the various AFS functions were described by AFS Secretary A. B. Sinnett. He called particular attention to the technical and research programs, the Training & Research Institute courses, and the consulting services available in safety, hygiene and air pollution control.—by Charles D. Ziel

Wisconsin Chapter

Hears Political Analysis

America's role in the current international situation was analyzed by Richard C. Hottelet, CBS news commentator, at the annual management program. In summary, he stated, "Our future will rest upon the power and leadership we show."—E. M. Sobota

Canton Chapter

L-D Melting Process

A review of the L-D melting process, both in this country and abroad, was given by J. M. Bertram, Kaiser Engineers. He suggested possibilities of the process for steel foundry production. A film illustrated principles of the process.—by Charles Stroup

WESTERN MICHIGAN—Ray Sutter, Sutter Products Co., Holly Mich., outlines the hot core box process.—by John McNamara

PITTSBURGH—Operational controls for ductile iron castings were explained by T. W. Curry, Lynchburg Foundry, Va., on left. K. E. Beck, Westinghouse Air Brake Co., was the discussion leader.—by Walter Napp

EASTERN CANADA—Coremaking with the CO_2 process was explained by T. H. Woods, Canadian Iron Foundry, Toronto. Woods, left, outlined the equipment necessary and how some present facilities could be used. Paul Piron congratulates the speaker.—Jim Cherrett

QUAD CITY—Jack H. Schaum, editor, MODERN CASTINGS, answers questions following talk on current and future developments in foundry operations. Ed Van Vooren, John Deere Malleable Works, East Moline, Ill., was technical chairman.—by Leo E. Osbourne

S. H. Cleland Presents Transactions to AFS

Forty-four volumes of AFS TRANSACTIONS dating back to 1912 have been donated to AFS by S. H. Cleland & Associates, Detroit.

In presenting the books Cleland wrote, "I have been a participant in the world-necessary foundry industry since 1906. The technical information gathered from TRANSACTIONS has kept me up to date on the remarkable advances made during that time period, especially in relation to the facinating study of all types of foundry sands.

"The industry has been wonderfully good to me, and other members of my family, and I hope that TRANSACTIONS will prove of equal value to other participants in their endeavors to produce better castings at lower cost."

Western Michigan Chapter

Sponsor Foundry Seminar

Chapter past chairmen again will sponsor a seminar for foundry instructors in the area high schools. Instructors who complete the course will receive credit from the University of Michigan.

Classroom and work shop facilities will be made available by Hackley Manual Training School in Muskegon. The first class meets Jan. 11 with a dinner and orientation program, through the cooperation of the AFS Central office. The Jan. 18 meeting will be an afternoon tour of the Muskegon Piston Ring Co. foundry at Sparta, Mich.

The seminar schedule:

Jan. 25	Metal Melting and Furnaces. Hackley Manual.
Feb. 1	Molding and Melting, Hackley Manual.
Feb. 8	Dinner meeting and general review. Bill Stern's restaurant.
Feb. 15	Molding and Melting, Hackley Manual.
Feb. 22	Cleaning and Finishing, Hackley Manual.
March 1	Sand Practice and Testing, Hackley Manual.
March 8	Plant visit to Alloyed Grairon Casting Corp., Ravanna.
March 15	Foundry Equipment and Supplies, Hackley Manual.
March 22	Final dinner meeting and summation.

Members of the education committee who will instruct in the classroom and laboratory are:

Lewis Hodges, professor of vocational education, University of Michigan; E. J. Huttenga, director of vocational and adult education, Muskegon Public School System; Dale Trumble, vocational instructor, Hackley Manual Training School; Joe Cannon, and Joe Schroeder, Enterprize Brass Co.; Adrian Archambault, Cannon-Muskegon Corp.; Charles Cousineau, Carpenter Bros.

Also: John Van Haver and Fritz DeHudy, Sealed Power Corp.; C. J. Lonnee, R. Lonnee, and R. Kriefeldt, Alloyed Grairon Castings Corp.; Dave Jacobson, Grand Haven Brass Co.; Frank Goetman, Standard Sand Co.; Elmer Carmody and Floyd Castle, Engineering Castings Corp.; Cecil Sundell, Walter Blackmer, and Joe Brooks, Muskegon Piston Ring Co.—J. L. Brooks

Chicago Chapter

Conducts Simultaneous Meetings

Equipment and engineering, iron, sand, and steel sessions opened the chapter's technical season.

G. DiSylvestro

J. H. Kaufman, National Engineering Co., discussed recent material handling developments in Europe. Vern Patterson, Vanadium Corp., spoke on cast iron metallurgy fundamentals. T. E. Barlow, Eastern Clay Products Dept., International Minerals & Chemical Corp., described formulations and effects of sand and clay additives. George DiSylvestro, American Colloid Co., explained veining and penetration to steel foundrymen.

Quad City Chapter

Furan Core Binders

Greater accuracy, fewer handling operations, the ability to cure in a hot box without sag or distortion, has attracted considerable interest to the new furfural binders. These were discussed recently by Victor M. Rowell, Archer-Daniels-Midland Co., Cleveland.

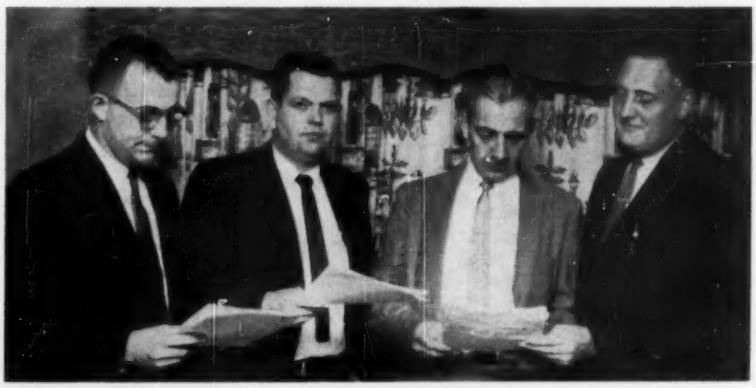
V. Rowell

The urea furan hot box technique is most efficient when used on cures such as automotive jacket cores, port cores, manifolds, small pipe fittings, valves and others of a similar nature. Materials successfully cast against these cores include gray iron, malleable, brass, bronze, and aluminum. Cores have ample hot strength to resist erosion by molten metal and have excellent collapsibility and shakeout characteristics.

Two types of furan resin binders are used. One, suitable for the jobbing shop making large castings with large cores, cures by chemical reaction without the application of heat.

A modified furan resin containing some urea has been developed for fabrication of small cores of light section and intricate design on a high production basis. This type is also cured by chemical action but the catalyst is relatively inert at room temperature providing a good bench life of several hours to the prepared sand.

Depending upon the individual resin, core box operating temperatures range from 350 to 475 F. The heat of the box activates the catalyst and converts the resin to a solid immedi-



WESTERN MICHIGAN—Planning the annual foundry instructors seminar are: Dale Trumble, vocational instructor, Hackley Manual Training School; Joe Cannon, Enterprize Brass Co. and president of the chapter's past chairmen; Adrian Archambault, Cannon-Muskegon Corp.; and E. J. Huttenga, director of vocational education, Muskegon Public School System.

ately. The core may be removed as soon as sufficient cured skin has been produced to allow handling.

Compared with shell cores, the following differences are noted; lower gas evolution, faster curing speed, simpler sand preparation, and lower binder cost.—by Leo E. Osbourne

Northeastern Ohio Chapter

Future Markets for Castings

Casting quality, uniformity, and delivery are three critical areas which must be solved by the metalcasting industry, Jack C. Miske, Foundry magazine, told Cleveland area foundrymen.

J. H. Miske

Increases in each of the major cast metals can be expected in 1965 as opposed to 1959. By types of metals, these increases were predicted: gray iron, 18 per cent; steel, 17 per cent; malleable iron, 3 per cent; ductile iron, 67 per cent; copper-base alloys, 16 per cent; aluminum alloys, 27 per cent; zinc-base alloys, 23 per cent.

Miske indicated that aggressive efforts by foundries will be needed to obtain these forecasts. Recommendations include the establishment of a marketing program, organization of a concerted sales effort, better human and public relations, and the sponsoring of sales and technical clinics for castings buyers.—by Wallace D. Huskonen

Texas Chapter

Ductile Iron Review

A high interest in ductile iron production in the chapter area was reported by J. H. Kimes, Jr., Tenn-Texas Alloy & Chemicals Corp.

J. H. Kimes

Kimes stated that ductile castings in this area were better than the average with a high degree of experimental work maintained. He recommended ductile iron as an excellent metal to replace weldments and forgings. Ductile castings can be designed and cast to give much better appearance than weldments and eliminate the high die costs of forgings. In addition castings can be obtained in small quantities. Kimes, through slides, demonstrated numerous examples of ductile replacing other means of fabrication.—by C. Eugene Silver

Tri-State Chapter

Ferroalloys in the Iron Foundry

A discussion of the electric arc furnace, the principal production unit in the ferroalloy industry, was presented by R. A. Clark, Union Carbide Metals Co., Div. Union Carbide Corp., Cleveland.

Clark compared the properties of the various sources of manganese and silicon for iron foundry use. He also discussed inoculants and alloyed cast irons.—by Bobby Bell

Utah Chapter

Gray Iron Foundry Control

Strict control of all operations has become essential in this era of increasing competition, Spencer Phillips, Ohio Ferro Alloys Corp., told Utah region foundrymen.

He pointed out that the success of a realistic quality control program hinges on the attitude of employees as well as employers, coupled with good supervisory control. Phillips pointed out that quality control starts with mathematically set control charts, establishing satisfactory operating standards. Past performance and rates are used to establish control limits.

After establishing operating standards, it is up to supervision to maintain operations within these standards. Once established, these standards also serve as guides enabling supervisors to pinpoint problems and takes the necessary correction action promptly.

National Director Arthur Falk, Centrifugal Castings Co., Long Beach, Calif., reviewed his laision duties between local chapters and AFS Headquarters. He also called attention to the improved quality and circulation of Modern Castings and urged all-out support of the 1961 Castings Congress and Exposition to be held in San Francisco during May.—by Phillip A. Sawyer.

Wisconsin Chapter

Makes Pledge to T&RI

A $2000 pledge for assistance in the building and equipping of the proposed AFS Training & Research Institute building has been approved.

At a recent meeting, $1000 was voted for the building fund as soon as ground has been broken and construction started. An additional $1000 will be available for equipment and facilities when instructors are employed and the basic curriculum established.

A concern about the growing shortage of technically trained personnel in the area at the present time and in the future together with satisfaction with the results of the T&RI courses prompted the action.

Rochester Chapter

Aluminum Foundry Practices

Elimination of large circular sprues in favor of tapered square sprues was recommended for the prevention of turbulence by Alan DeRoss, Kaiser Aluminum & Chemical Sales, Inc. The tapered sprue will prevent agitation in addition to serving as a choke.

In discussing degassing, DeRoss suggested the use of chlorine or nitrogen letting it bubble gently through the melt. Other suggestions were the use of pills or powders generally containing hexachlorethane.

Potential strength values can be given alloy H.P. 356 with heat treatment, said DeRoss.—by Haerle D. Wesgate

Student Chapters, Faculty Advisors

University of Alabama—Advisor, Prof. Warren C. Jeffery.

Brooklyn Polytechnic Institute—Advisor, Prof. William H. Ruten.

University of Illinois—Advisor, Prof. James L. Leach.

Massachusetts Institute of Technology—Prof. Howard F. Taylor.

Michigan State University—Instructors, Harry Bradshaw and Prof. H. L. Womochel.

University of Michigan—Advisor, Dr. R. A. Flinn.

Missouri School of Mines—Advisor, Prof. Robert V. Wolf.

Ohio State University—Advisor, Dr. D. C. Williams.

Oregon State College—Advisor, Prof. Lloyd M. Frazier.

Pennsylvania State University—Advisors, Prof. A. B. Draper and Prof. W. P. Winter.

Texas A & M College—Advisors, Prof. Edward D. Kranz and Prof. Stewart E. Brown.

University of Wisconsin—Advisor, Prof. Richard W. Heine.

Wentworth Institute—Advisor, J. Gerin Sylvia.

AFS Chapter Meetings

DECEMBER

Birmingham District . . *No Meeting.*

Canton District . . **Dec. 1** . . Mergus Restaurant, Canton, Ohio . . H. E. Figgie, Jr., *"Profitable Foundry Operations." Management Night.*

Central Illinois . . **Dec. 10** . . American Legion Hall, Peoria, Ill. . . *Party.*

Central Indiana . . **Dec. 5** . . Athenaeum Turners, Indianapolis . . J. S. Schumacher, Hill & Griffith Co., *"Sand Testing versus Molding Methods."*

Central Ohio . . **Dec. 12** . . Seneca Hotel, Columbus, Ohio . . J. Barrabee, Hoover Ball & Bearing Co., *"Quality Control."*

Chesapeake . . **Dec. 2** . . Engineers Club, Baltimore, Md. . . J. H. Schaum, Modern Castings, *"What's New in Metalcasting."*

Chicago . . **Dec. 5** . . Chicago Bar Association, Chicago . . F. W. Less, Hooker Chemical Co., *"Shell Cores and New Shell Sand."*

Cincinnati District . . **Dec. 17** . . Netherland Hilton Hotel . . *Christmas Party.*

Connecticut . . **Dec. 14** . . Waverly Inn, Cheshire, Conn. . . *Christmas Party.*

Corn Belt . . **Dec. 17** . . Town & Country Restaurant, Lincoln, Neb. . . . *Christmas Party.*

Eastern Canada . . **Dec. 2** . . Mount Royal Hotel, Montreal, Que. . . H. W. Schwengel, Modern Equipment Co., *"New Developments in Water-Cooled Cupolas."*

Metropolitan . . **Dec. 9** . . Military Park Hotel, Newark, N. J. . . *Christmas Party.*

Michiana . . **Dec. 12** . . Club Normandy, Mishawaka, Ind. . . Dr. O. A. Sander, Marquette University, *"The Foundry Silicosis Problem Can be Licked."*

Mid-South . . **Dec. 10** . . *Christmas Party.*

Mo-Kan. . . **Dec. 3** . . President Hotel . . *Christmas Party.*

Northern California . . **Dec. 12** . . Spenger's Fish Grotto, Berkeley, Calif.

Northern Illinois & Southern Wisconsin . . **Dec. 3** . . *Christmas Dinner Stag.*

Northeastern Ohio . . **Dec. 9** . . *Christmas Party.*

Northwestern Pennsylvania . . *No Meeting.*

Ontario . . **Dec. 9** . . Royal Connaught Hotel, Hamilton, Ont. . . R. C. Shnay, Canada Iron Foundries, *"Recent Developments in the Production of Ductile Iron"*; G. M. Johnston, Neptune Meters Ltd., *"Ingot and Casting Quality in Bronze Alloys"*; A. Kavosi, Jr., Auto Specialties Mfg. Co., *"Pearlitic Malleable."*

Oregon . . **Dec. 17** . . Multnomah Hotel, Portland, Ore. . . *Dinner Dance.*

Philadelphia . . **Dec. 6** . . Benjamin Franklin Hotel, Philadelphia . . *Christmas Party.*

Pittsburgh . . **Dec. 12** . . Penn-Sheraton Hotel, Pittsburgh . . *Christmas Party.*

Rochester . . **Dec. 6** . . Manger Hotel, Rochester, N. Y. . . J. A. Mueller, Carborundum Co., *"Snagging and Cut-Off."*

Saginaw Valley . . **Dec. 1** . . Fischer's Hotel, Frankenmuth, Mich. . . W. Buel, Aristo Corp., *"Newest in Core Binders."*

St. Louis District . . **Dec. 8** . . Edmonds Restaurant . . C. A. Sanders, American Colloid Co., *"Foundry of the Future."*

Southern California . . **Dec. 9** . . Rodger Young Auditorium, Los Angeles . . *Panel (Local Foundrymen).*

Tennessee . . *No Meeting.*

Texas . . **Dec. 9** . . Houston Engineering & Scientific Society, Houston, Texas . . C. F. Lewis, Cook Heat Treating Co., *"Fundamentals of Heat Treatment."*

Toledo . . **Dec. 7** . . Heatherdowns Country Club, Toledo, Ohio . . W. R. Oakley, Delhi Foundry Sand Co., *"CO_2 Process."*

Twin City . . **Dec. 10** . . Midland Hills Country Club, St. Paul, Minn. . . *Party.*

Western Michigan . . **Dec. 3** . . Muskegon Country Club, Muskegon, Mich. . . *Christmas Party* . . **Dec. 5** . . Black Angus Restaurant, Muskegon, Mich. . . W. R. Weaver, Modern Plastics & Pattern, Inc., *"New Applications in Pattern Making."*

Western New York . . **Dec. 2** . . Sheraton Hotel, Buffalo, N. Y.

Wisconsin . . **Dec. 9** . . Hotel Schroeder, Milwaukee . . *Christmas Party.*

JANUARY

Birmingham District . . **Jan. 13** . . Thomas Jefferson Hotel, Birmingham, Ala. . . W. R. Bond, *Management Night.*

British Columbia . . **Jan. 20** . . Leon's, Vancouver, B. C.

Canton District . . **Jan. 5** . . Brookside Country Club, Barberton, Ohio . . *Panel Discussion.*

Central Illinois . . **Jan. 9** . . Vonachen's

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Circle No. 135, pages 157-158

Junction, Peoria, Ill. . . C. A. Sanders, American Colloid Co., *"A Look at Future Foundries."*

Central Indiana . . Jan. 9 . . Anthenaeum Club, Indianapolis.

Central Michigan . . Jan. 18 . . Hart Hotel, Battle Creek.

Chesapeake . . Jan 14 . . American Legion Hall, Parkville, Md. . . Oyster Roast Jan. 27 . . Baltimore Engineer's Club, Baltimore, Md. . . J. J. O'Brien, Foundry Core Supply Co., *"Shell Cores."*

Chicago . . Jan. 9 . . Chicago Bar Association, Chicago . . *Past Presidents' Night.*

Cincinnati District . . Jan. 9 . . Wigwam Restaurant, Cincinnati.

Connecticut . . Jan. 24 . . Waverly Inn, Cheshire, Conn. . . R. B. Fischer, Ingersoll Rand Corp., *"Gating & Risering in the Foundry."*

Detroit . . Jan. 19 . . Wolverine Hotel, Detroit . . G. Solga, Kelsey-Hayes Co., *Film, Kelsey-Hayes Foundry Operations.*

Eastern Canada . . Jan. 13 . . Sheraton Mount Royal Hotel, Montreal, Que. . . Round Table Discussion, Discussion Leaders: *Cast Iron*: J. C. Kinsella, Canada Iron Foundries, Ltd., *Steel*: M. O. Diorio, Dominion Brake Shoe Co. Ltd., *Non Ferrous*: J. Dick, Montreal Bronze Ltd.

Eastern New York . . Jan. 17 . . Panetta's Restaurant, Menands, N. Y.

Metropolitan . . Jan. 9 . . Military Park Hotel, Newark, N. Y. . . G. M. Etherington, American Brake Shoe Co., *"Shell Cores"*, G. N. Davis, Cooper Alloy Corp., *"CO_2 Cores"*, R. M. Overstrud, Reichhold Chemical Industries, *"Self Curing Core Binders."*

Michiana . . Jan. 9 . . Club Normandie, Mishawka, Ind. . . Edward C. Mathis, Pickands Mather Co., *"Cupola Melting Practice"*, F. L. Riddell, H. Kramer & Co., *"Metallurgical Control in the Brass Foundry."*

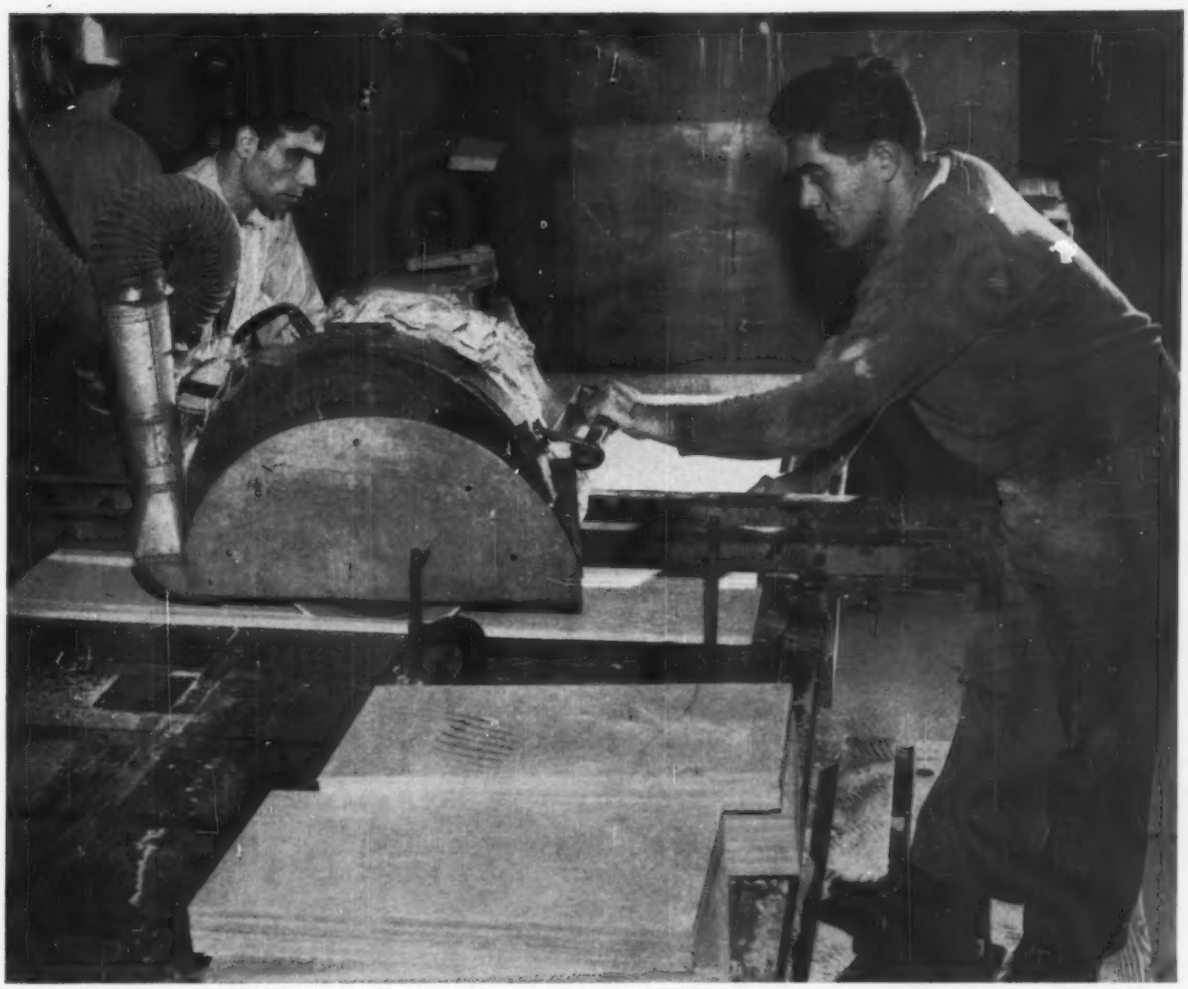
Mid-South . . Jan. 13 . . Claridge Hotel, Memphis, Tenn. . . D. Gerlinger, Milwaukee Foundry Equipment Co., *"Pressure Molding."*

Mo-Kan . . Jan. 19 . . Fairfax Airport, Kansas City, Kan. . . G. Koren, Beardsley & Piper, *"What Shell Sand Coating Process and Why Shell Cores for Your Foundry."*

Northeastern Ohio . . Jan. 12 . . Manger, Hotel, Cleveland . . Prof. L. Lawrence, Alfred University, *"Characteristics of Foundry Sands and Bonding Agents."* (First of Symposium Series)

Northern California . . Jan. 16 . . Spenger's Fish Grotto, Berkeley, Calif.

Northern Illinois & Southern Wisconsin



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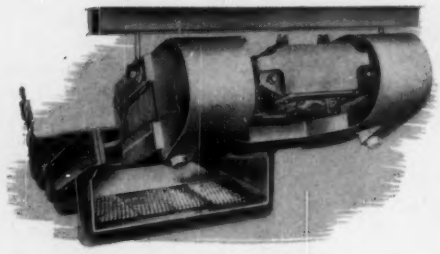

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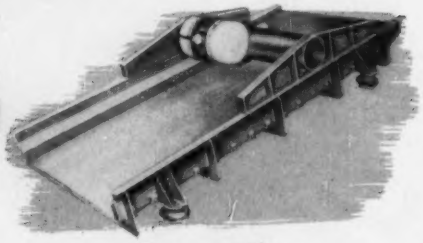

Rotary Vibrator

Whatever your screening problem, SYNTRON builds a vibrating screen for almost every screening need.

SYNTRON Vibrating Screens have been tested and proven in many screening applications—sizing, de-watering, media recovery, wet and dry sizing and fine screening. Uniform quality control screening means consistently high quality products.

SYNTRON Screens offer efficiency, dependability and low maintenance for better screening, higher capacity at lower cost.

Write for the catalog section on Vibrating Screens

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545 Lexington Ave. Homer City, Penna.

Other SYNTRON Equipment of proven dependable Quality

VIBRATORY FEEDERS

TEST SIEVE SHAKERS

LAPPING MACHINES

Circle No. 137, pages 157-158

. . **Jan. 10** . . Rockford Country Club, Rockford, Ill. . . W. R. Jaeschke, Whiting Corp., *"Cupola Operation."*

Northwestern Pennsylvania . . **Jan. 23** . . Amity Inn, Erie, Pa. . . Lester B. Knight, Lester B. Knight Associates, *"Mechanization and Modern Foundry Practice."*

Ontario . . **Jan. 20** . . Seaway Hotel, Toronto . . D. L. Watson, Emco Ltd. and W. R. Moggridge, Canada Iron Foundries, Ltd., *"The Foundry Industry and Quality Control."*

Oregon . . **Jan. 18** . . Heathman Hotel, Portland, Ore.

Philadelphia . . **Jan. 13** . . Engineers' Club, Philadelphia . . R. Lash, Lebanon Steel Foundry, *"Modern Cleaning Techniques."*

Piedmont . . **Jan. 13** . . Virginian Hotel, Lynchburg, Va. . . T. Barlow, International Minerals and Chemical Co., Eastern Clay Products Div., *"Castings Defects as Related to Sand Practice."*

Pittsburgh . . **Jan. 16** . . Hotel Webster Hall, Pittsburgh, Pa. . . S. F. Carter, American Cast Iron Pipe Co., *"Electric Furnace Practice for Steel Castings."*

Quad City . . **Jan. 16** . . Le Claire Hotel, Moline, Ill. . . *Panel Discussion.*

Rochester . . **Jan. 3** . . Manger Hotel, Rochester, N. Y. . . F. W. Less, Hooker Chemical Corp., Durez Plastics Div., *"Resin Coated Sand and Its Fundamentals."*

Saginaw Valley . . **Jan. 5** . . Fischer's Hotel, Frankenmuth, Mich. . . W. Putnik, Chev. Saginaw Grey Iron Foundry Div., R. Harrison, Saginaw Malleable Iron, D. Des Jardins, Eaton Manufacturing Co., *"Material Handling in Saginaw Valley Foundries."*

St. Louis District . . **Jan. 12** . . Edmonds Restaurant, St. Louis . . R. T. Lewis, Keen Foundry Co., *"Are Your Costs Reliable."*

Southern California . . **Jan. 13** . . Rodger Young Auditorium, Los Angeles . . J. Marden, Eutectic Welding Alloy Corp., *"New Welding Procedures."*

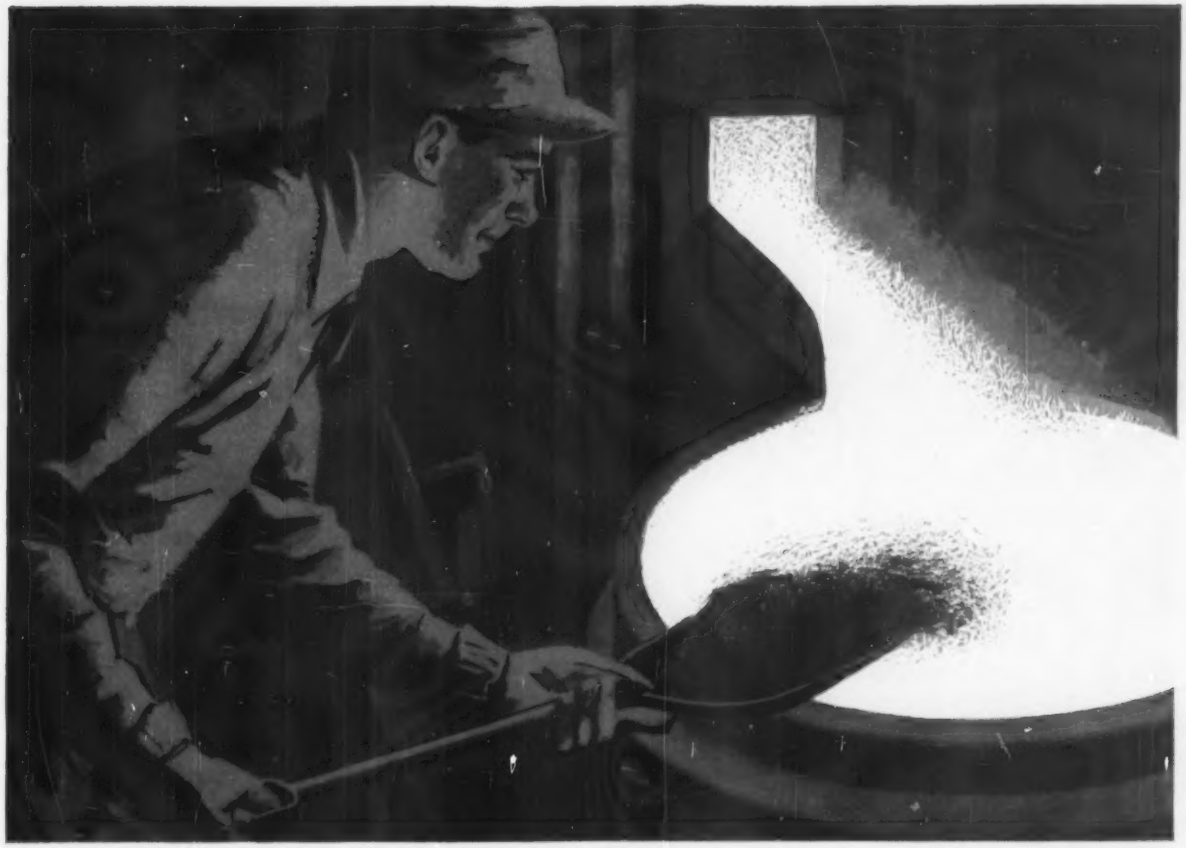
Tennessee . . **Jan. 27** . . Wimberly Inn, Chattanooga, Tenn. . . W. A. Hambley, Chas. A. Krause Milling Company, *"Gray Iron Foundry-Sand Practice."*

Texas . . **Jan. 20** . . Baker Hotel, Dallas, Texas . . R. A. Colton, American Smelting & Refining Co. Federated Metals Div., *"What's New in Non-Ferrous."*

Toledo . . **Jan. 4** . . Heatherdowns Country Club, Toledo, Ohio . . *"Plastic Pattern vs Aluminum Pattern."*

Tri-State . . **Jan. 13** . . Tulsa, Okla.

Twin City . . **Jan. 10** . . Jax Cafe, Minne-



dependable Molybdenum in the foundry

Primary justification for increased success in foundry applications of molybdenum is found in the dependability of results. Day after day the foundryman gets the results he needs by adding molybdenum to his melt. Molybdenum may be added to improve tensile and transverse strength, increase impact and fatigue strength, improve wear resistance, increase toughness and strength at higher temperatures, intensify effects of other alloying elements.

The consistency of results in production justifies confidence in MCA molybdenum.

MCA closely controls all of its manufacturing steps and the chemistry of its molybdenum products, hence the uniformity of results.

Complete stocks of molybdenum in all of its metallurgical forms are available through MCA. Technical assistance in meeting tough specifications or solving specialized problems is yours upon request. No obligation, of course.

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Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

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apolis . . G. L. Armstrong, U. S. Reduction Co., *"Aluminum Gating and Feeding Practice."*

Utah . . Jan. 13 . . Salt Lake City . . F. Wheel, Ajax Precision Machine Co., *"Aluminum."*

Western Michigan . . Jan. 6 . . Spring Lake Country Club, Grand Haven, Mich. . . *Plant Visitation, Grand Haven Brass Co. Movie on "Taconite."*

Western New York . . Jan. 6 . . Sheraton Hotel, Buffalo, N. Y.

Wisconsin . . Jan. 13 . . Hotel Schroeder, Milwaukee . . N. N. Amrheim, Moderator, Federal Malleable Co. Panel Members: Robert Eck, Eck Foundries, George Antonic, Motor Castings Co., E. Gibson, Grede Foundries, Inc., *"Practical Aspects of Quality Control." General Meeting.*

F.E.M.A. Re-Elects Officers

Foundry Equipment Manufacturers Association officers were re-elected at the recent annual meeting. They are: President, E. A. Borch, National Metal Abrasive Co., Cleveland; 1st Vice-President, R. A. Brackett, Spencer Turbine Co., Hartford, Conn.; 2nd Vice-President, C. G. Hawley, Jeffrey Mfg. Co., Columbus, Ohio; Executive Secretary-Treasurer, C. R. Heller, Washington, D. C.

Foundry Trade News

Gray Iron Founders' Society . . . has elected John E. McIntyre, Sibley Machine & Foundry Corp., South Bend, Ind., president. Other officers are: vice-president, Cecil Garland, W. O. Larson Foundry Co., Grafton, Ohio; secretary, J. T. Boyd, Goldens' Foundry & Machine Co., Columbus, Ga.; treasurer, Paul H. Scherf, Alten Foundry & Machine Works, Inc., Lancaster, Ohio; assistant treasurer, W. F. Seelbach, Forest City Foundries Co., Cleveland. Donald H. Workman was re-appointed executive vice-president.

New directors are: James Crowley, Pioneer Foundry Co., Jackson, Mich.; Paul W. Kluge, Tower Grove Foundry, St. Louis; Robert F. Pohlman, Pohlman Foundry Co., Buffalo, N. Y.; and Will H. Sanburn, Springfield Foundry Co., Indian Orchard, Mass.

Four industry members were hon-

For the first time, a Foundry Educational Foundation scholarship has been awarded to a father and son. Jules Henry, Missouri Steel Casting Co., Joplin, Mo., third from left, received one of the first F.E.F. scholarships at Case Institute of Technology. Recently his son, Daniel T. Henry, fourth from left, a student at the Missouri School of Mines, received his F.E.F. scholarship. On the far left are E. J. Walsh, Executive Director, F.E.F., and AFS Regional Vice-President Webb Kammerer, Midvale Mining & Mfg. Co., and a F.E.F. trustee. On right is Dean C. L. Wilson, Missouri School of Mines.

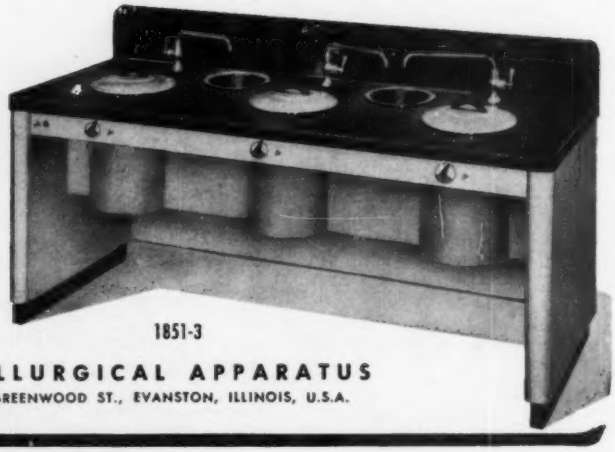
Polimet

A NEW NAME IN METALLOGRAPHIC POLISHERS

- VARIABLE SPEED—100-1200 r.p.m.
- QUIET OPERATION
- VIBRATION FREE
- EASY CONTROL
- HIGH TORQUE—½ h.p.
- AVAILABLE IN 1, 2 or 3 UNIT TABLES
- INTERCHANGEABLE BALANCED WHEELS
- VITREOUS FINISHED, EASY TO CLEAN BOWL

With infinitely variable speed over a wide range it is possible for the operator to select the exact speed desired for the particular sample at hand. The complete speed range is controlled by turning a knob. No cranking is required to change speed, no belts, pulleys or mechanical clutches are used, eliminating the source of most vibration present in other variable speed polishers. The electronic control is accomplished through the use of only one vacuum tube and the complete electronic circuit is mounted on a 4" x 4" panel easily accessible on the outside of the motor.

The 1851 Polimet series is furnished in the Buehler steel polishing tables, finished in silver gray hammertone. The top and edges of the table are black formica. One, two, or three unit tables are available.



1851-3

Buehler Ltd. METALLURGICAL APPARATUS
2120 GREENWOOD ST., EVANSTON, ILLINOIS, U.S.A.

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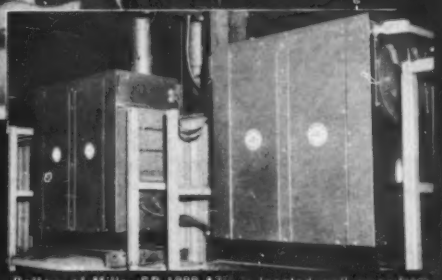
Foundries Find

miller-powered carbon arc cutting

Faster — Cheaper — Better

These photos, taken in well-known foundry, show operator carbon-arc cleaning a casting using an Arcair torch powered by a Miller SR-1000-A7. Note handiness of control console.



Battery of Miller SR-1000-A7's is located well away from cleaning room.

THE MILLER MODEL SR-1000 series, providing 1000 amperes of d-c at 40 arc volts, 100% duty cycle, has proved to be the ideal power source for Arcair and other foundry carbon arc cutting processes. Designed and built around Miller's exclusive semi-metallic, completely sealed Gold Star rectifier, drastic overloads are handled routinely without failure or deterioration. Control console is instantly removable to any reasonable distance. Adjustment of current range from 200 to 1400 amperes is accomplished under load. What's more, the operator can switch in a flash from cleaning and gouging to welding when needed. Operates from three phase power lines.

For applications involving carbon arc cutting, heavy submerged arc welding, plasma jet and electric furnace processes, the Miller SR-1000 series is probably without an equal. May we send you more complete details and specifications?

MODEL SR-1000-A7

miller ELECTRIC MANUFACTURING COMPANY, INC.

Distributed in Canada by Canadian Liquid Air Co., Ltd., Montreal

APPLETON, WISCONSIN

Circle No. 134, pages 157-158

ored for their contributions to the society and industry. They are: Charles R. Gregg, Gregg Iron Foundry, El Monte, Calif.; J. Edward Quest, formerly with Shakopee Foundry Co., Shakopee, Minn.; J. T. Boyd, Golden's Foundry & Machine Co., Columbus, Ga.; and Albert M. Nutter, E. L. LeBaron Foundry Co., Brockton, Mass.

Non-Ferrous Founders' Society . . . has elected Elmer G. Brummund, Jr., Brummund Foundry Co., Chicago, president. Other officers are: 1st vice-president, Dan A. Mitchell, Progressive Brass Mfg. Co., Tulsa, Okla.; 2nd vice-president, L. J. Andres, Lawran Foundry Co., Milwaukee. Herbert F. Scobie was re-elected executive secretary. Executive committee members are Brummund, Mitchell, Andres, retiring N.F.F.S. president M. E. Nevins, George W. Stewart, East Bay Brass Foundry Co., Richmond, Calif.; R. E. Dickison, Brass Foundry Co., Peoria, Ill.; and N. W. Meloon, Meloon Bronze Foundry Co., Syracuse, N. Y.

E. G. Brummund

D. A. Mitchell

National directors elected to three-year terms in addition to Brummund and Stewart, are: C. O. Eilertson, Boston Pattern Works, Norwood, Mass.; J. W. Horner, Slack-Horner Brass Mfg. Co., Longmont, Colo.; and C. T. Koehler, Hamilton Brass & Aluminum Castings Co., Hamilton, Ohio. E. W. Horlebein, Gibson & Kirk Co., Baltimore, Md., was elected a director at large. John C. Emery, Jr., Racine Foundry & Mfg. Co., Detroit, was named a national director to fill an unexpired term.

Chester K. Faunt, Faunt Foundry Co., received the society's distinguished service award for his role in the organization of the society.

Central Foundry Div. . . . General Motors Corp., has become the first in the United States to mass produce aluminum cylinder heads and blocks. New, light-weight V-8 water-cooled engines are being made for Buick, Oldsmobile, and Pontiac at the Defiance, Ohio, plant. Blocks are produced in semi-permanent mold machines using water-cooled metal dies and sand cores. Precast gray iron cylinder liners or sleeves are cast integrally within the block and poured in a vertical position. Cylinder heads are cast in a horizontal position. Following machining, castings are heat treated to relieve stresses and provide dimensional stability.

GM pearlitic malleable crankshafts are produced at the Danville, Ill., plant for these engines. Crankshafts are also made for the regular Pontiac V-8 engine and the GMC Truck & Coach Div. 305 cubic inch V-6 engines.

Kaiser Refractories & Chemicals Div. . . . Kaiser Aluminum & Chemical Corp., is constructing a new technical center at Mexico, Mo. The center will be a 17,300 square feet single story structure devoted to offices, a testing furnace building, and a laboratory building. The center will house the division's clay research staff and raw materials group.

Ernest A. Hund Co. . . . Fort Thomas, Ky., has been formed by E. A. Hund. As a manufacturers' representative, the company will serve the area including southern Ohio, southern Indiana, and Kentucky.

James B. Clow & Sons, Inc. . . . Chicago, has purchased the assets and business of Streator Drain Tile Co., Streator, Ill., for approximately $2,500,000.

Steel Founders' Society of America . . . fourth product development contest is now underway. Entries must be postmarked prior to June 1, 1961. Prizes totalling $10 000 will be awarded in five fields.

Find out for yourself...

why **STEVENS**
sells more
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than anyone else
in the world!

Just fill out the coupon
below for a *free* test sample.

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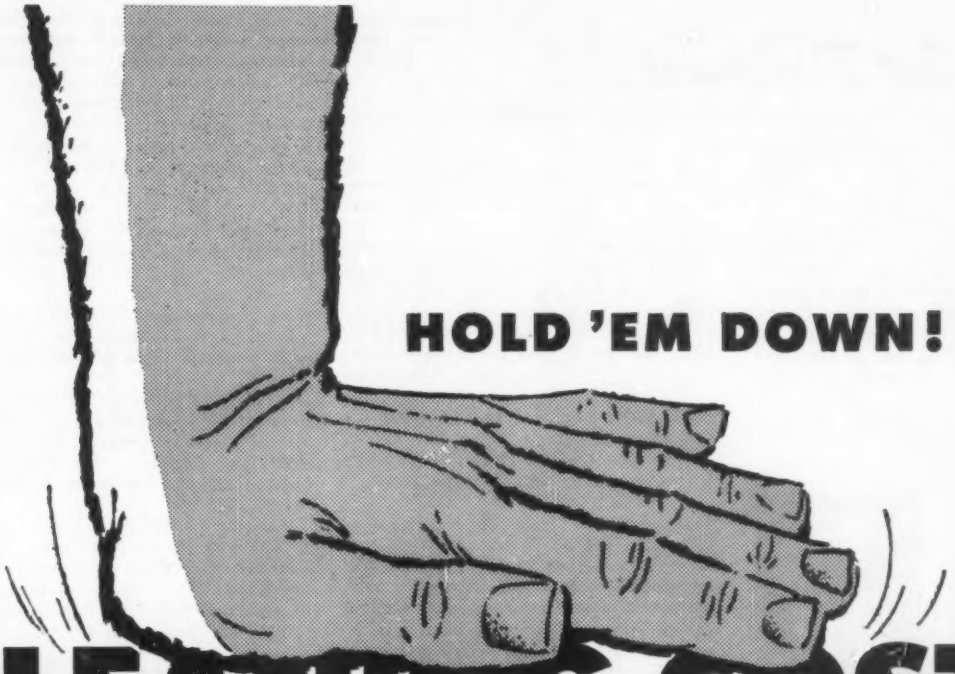

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CLEANING COSTS

Now, there's a *new* and *dependable* way to reduce cleaning costs — without sacrificing cleaning efficiency! For METAL BLAST has an entirely new and more economical process* for making steel abrasives — and passes the savings along to consumers.

Now, you can make substantial savings on cleaning or descaling costs simply by changing over to "SUPER-STEEL" steel shot and grit. At $165.00 per ton, you'll really save money! And, you'll still enjoy fast and thorough cleaning, low abrasive consumption and low maintenance costs. As a matter of fact, "SUPER-STEEL" is *guaranteed* to equal the performance of any other steel abrasive.

Consider what you're now paying for steel abrasives — probably upwards of $200.00 per ton! Why pay this high price, when new "SUPER-STEEL" costs so much less? Why not check this new, economical abrasive? Write, wire or phone collect for test samples.

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ALSO IN: Chattanooga • Chicago • Cincinnati • Dayton • Detroit • Elberton, Ga. Grand Rapids • Greensboro, N. C. • Houston • Los Angeles • Louisville Milwaukee • Minneapolis • New York • Philadelphia • Pittsburgh and St. Louis.

MANUFACTURERS, ALSO, OF TOP QUALITY "SEMI-STEEL" SHOT AND GRIT, MALLEABLE AND CHILLED SHOT AND GRIT — AT COMPARABLE SAVINGS!

"SUPER-STEEL"

STEEL SHOT *and* GRIT

$165.00 *per ton* in truck loads

Circle No. 142, pages 157-158

Let's Get Personal . . .

James R. Bachman . . . has been appointed manager of the basic refractories laboratory at Milpitas, Calif., for Kaiser Refractories & Chemicals Div., Kaiser Aluminum & Chemical Corp., Oakland, Calif. Bachman who has served at the laboratory since 1957 succeeds **Berton G. Altmann** who has been named assistant to the director of research and development.

Warren M. Loucks . . . now sales engineer, Thiem Products, Inc., Milwaukee, covering western Pennsylvania.

W. M. Loucks

A. P. Taber

Alden P. Taber . . . elected a vice-president, Babcock & Wilcox Co. and heads the research and development division.

Robert A. Titlow . . . Central Foundry Div., General Motors Corp., made general superintendent, Bedford, Ind., plant; **Robert P. Hendrichs,** plant manager, Jones Mills, Ark., plant. **George A. Hach,** sales manager, non-ferrous metals, Saginaw, Mich.

John C. Douglas . . . has been appointed vice-president of operations and **David Swan** vice-president of technology for Union Carbide Metals Co., Div. Union Carbide Corp. Douglas has been with Union Carbide Metals Co. since 1934 and vice-president of technology since 1957. Swan has been with the corporation since 1946 and since 1959 has been manager of planning. **D. E. Stingel** has been appointed works manager, he has been vice-president of Carbide Power Co. and production manager of Union Carbide Olefins Co. since 1958. **H. J. Pfeifer** has been appointed manager of the Phillipsburg (Calif.) district. He has been manager of the corporation's San Francisco office since 1956.

Frank B. Gatley . . . vice-president of the Flynn & Emrich Co., foundry division, Baltimore, Md., has retired after 40 years service with the company.

George J. Peer . . . has been named sales manager of furnace products for Basic, Inc., Cleveland. He was formerly midwestern district sales manager with headquarters in Hammond, Ind. **G. W. Edwards,** formerly central district sales manager, succeeds Peer. **D. Bedell Baxter** succeeds Edwards.

Roy K. Cannon . . . is the newly appointed sales manager of the Electro-Alloys Div., American Brake Shoe Co.

Charles E. Kendall . . . until recently a vice-president of The Connecticut Bank and Trust Co., has been named president, treasurer, and general manager of the Connecticut Casting Corp., Stonington, Conn. Former president **Patrick J. Dwyer** becomes chairman of the board.

Dr. Cataldo Cialdella . . . is director of research and development, Hysol Corp., New York, and **James P. Hornburg,** supervisor of technical services.

Edward F. Koglin . . . is now director of development, G. E. Smith, Inc., McKees Rocks, Pa.

Alfred J. Murrer . . . is now assistant factory manager, Gleason Works, Rochester, N. Y. Other appointments: **Haerle D. Wesgate,** superintendent, foundry and patternshop; **John H. Foster,** superintendent, cutter division; **Donald L. Whitmore,** product development engineer given additional responsibilities of liaison engineer, Gleason Works, Ltd., England; **Walter E. Andrus,** assistant production manager; **David D. Somers,** assistant export manager.

Frank W. Button . . . is now foundry superintendent, Haynes Stellite Co., Kokomo, Ind.

Kent S. Clow, Jr. . . . named to newly created post of assistant to the president, James B. Clow & Sons, Inc., Chicago.

Franklin Pai-Heng Chen . . . who has worked as an engineer in China, Formosa, and Pittsfield, Mass., has joined General Electric Co. foundry, Schenectady, N. Y.

K. Herron . . . named eastern division sales manager, Alloys & Chemicals Corp., Cleveland. Area covers Cleveland, Pittsburgh, New York, and Indianapolis districts.

Charles E. Peterson . . . named division manager in charge of MacIntosh-Hemphill Div., E. W. Bliss Co. succeeding **J. R. Patterson.** Plants are in Pittsburgh and Midland, Pa.

John F. Roth . . . now president, Cleveland Standard Pattern Works Inc., Cleveland.

J. F. Roth

R. S. Reimers

Robert S. Reimers . . . is now technical service representative, Foundry Services Inc., Cleveland, covering northern Illinois and Iowa.

Charles B. Saunders . . . sales consultant, Tennessee Products & Chemical Corp., Nashville, Tenn., has retired. He was associated with Tennessee Products since 1947 and is a past chairman of the AFS Birmingham Chapter.

Jerome C. Pardo . . . is engineering representative, Harry W. Dietert Co., Detroit, for state of Pennsylvania.

Charles E. Haney . . . is new vice-president, Electric Steel Foundry Co., Portland, Ore., will continue to function as works manager, foundry production departments. **Leroy Fink** is responsible of managing analytical department in addition to supervising metallurgist-operations. **Laurence J. Venne,** assistant to

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president-metallurgy also manages radiographic department. **Lawrence Gillen** named manager of sales, foundry products.

R. J. Foresman . . . made new vice-president, Michigan Abrasive Co., Detroit.

James A. Michel . . . is now eastern division manager of electrode products for National Carbon Co., Div., Union Carbide Corp.

E. L. Shaughnessy . . . Milwaukee, named sales manager, western division, Dayton Oil Co., Dayton, Ohio.

John McCormick . . . is plant manager, Jelrus Precision Casting Co. plant, New York, recently acquired by Casting Engineers, Chicago.

Ernest S. Frens . . . new manager, manufacturing engineering, foundry dept., General Electric Co., Schenectady, N. Y.

Robert L. Humphrey . . . named to sales representative, Alloys & Chemicals Corp., Cleveland.

H. J. Weber . . . AFS Director of Safety, Hygiene and Air Pollution, and whose column appears regularly in MODERN CASTINGS, has been appointed regional coordinator of the Chicago section, American Industrial Health Assoc. Also the same section has just named him chairman of a TV-script-writing team to prepare material on "What is Industrial Hygiene?" The program will be shown on Chicago's educational TV station.

Bernard M. Korn . . . is treasurer, American Steel Foundries has been assistant treasurer since 1959.

B. M. Korn

R. Thompson

R. Thompson . . . chief metallurgist Dominion Engineering Works, Ltd., Montreal, Can., has been awarded the silver medal by the Steel Casting Institute of Canada for outstanding and meritorious service to the steel foundry industry in Canada.

J. James Offutt . . . appointed vice-president and general manager, A. P. Green Fire Brick Co. Other appointments: **Jack W. Swatek,** director of sales **H. L. Beynon,** general sales manager **W. Ferris Munday,** plant manager of Mexico, Mo., operation **W. D. Clark,** manager of all Green Co. plants outside of Mexico, Mo.

John Hood . . . named general manager, Grand Rapids Foundry Div., Oliver Machinery Co., Grand Rapids, Mich.

Clifford M. Apgar . . . named manager, shop operations, General Electric Co. specialty foundry, Schenectady, N. Y.

George R. Rittenhouse . . . named treasurer, **John E. Hartshorn** as secretary, General Refractories Co., Philadelphia.

Rodney E. Hanes . . . made vice-president, operations foundry and machinery group, Blaw-Knox Co., Pittsburgh, Pa.; succeeded by **Earl E. Vance.**

Carl Kilian . . . is now sales engineer, Albert Lea Foundry, Div. Queen Products, King-Seeley Corp., Albert Lea, Minn.

Max K. Ruppert . . . appointed general sales manager, Kensington Steel Div., Poor & Co., Chicago.

Fred S. Holway . . . appointed assistant vice-president, Castner, Curran & Bullitt, Inc., New York, a subsidiary of Eastern Gas and Fuel Associates. Holway was sales manager, Mystic Iron Works.

Increase your profits with DFC crucibles & funnels

Since 1876, DFC has furnished crucibles, clay goods, and accessory materials which have set *standards of quality the world over*. More recently the unanimous acceptance and wide use of DFC transfer crucibles and funnels by the precision casting industry, is high testimony to their economy and dependability.

For precision casting...lost wax, investment and permanent mold. Transferring, pouring, spouting... there is a DFC crucible or funnel to meet your exact needs.

If you have a special crucible problem, let us work on it for you.

Denver Fire Clay Company

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The DENVER FIRE CLAY COMPANY DFO-5
3039 Blake Street, Denver 17, Colorado

Please send me further information on your full line of crucibles.

Name.....

Company.....

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City and State.....

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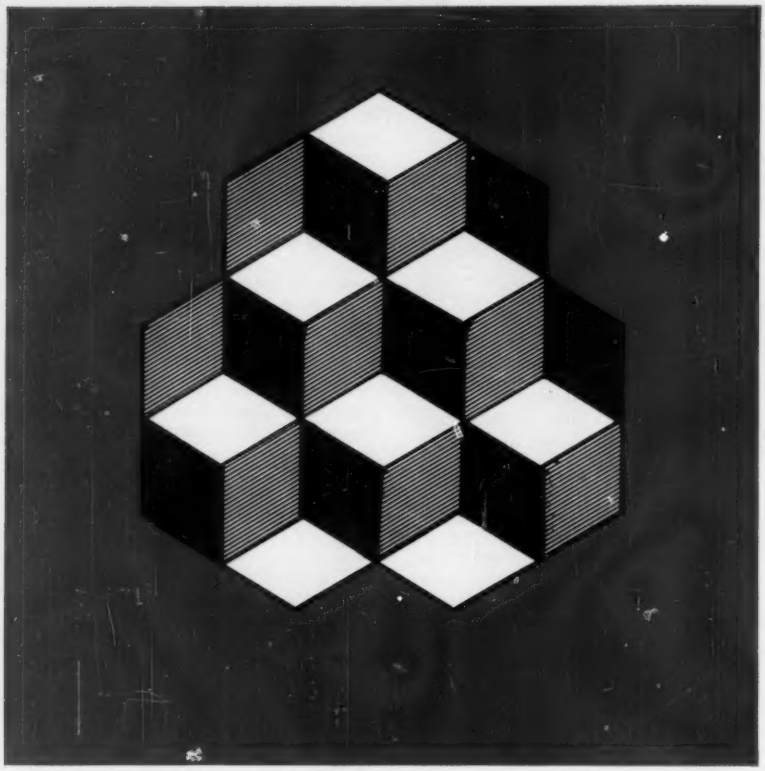

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Count the cubes in the figure. You'll see six or seven, depending upon your point of view. Consider the total value of your present abrasive, and compare it with the proven value of Wheelabrator Steel Shot. Not just in price, but in abrasive consumption, cleaning speed, cleaning quality, and equipment maintenance costs as well. From any point of view, the proven quality of Wheelabrator Steel Shot adds up to extra value and extra profit.

Write today for this new handbook of blast cleaning abrasive performance. It's full of charts and facts you can use to help cut abrasive consumption, reduce cleaning costs. Write to Wheelabrator Corp., 630 S. Byrkit St., Mishawaka, Ind. In Canada, P. O. Box 409, Scarborough, Ont.

WHEELABRATOR
STEEL ABRASIVES

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obituaries

William J. Gallana . . . manager of the Alloy Sales Div., E. J. Lavino Co., Philadelphia. He had been in the foundry industry for more than 40 years and for many years was AFS Philadelphia Chapter Entertainment Chairman.

Fred J. Meyers, director of purchases, GHR Foundry Div., Dayton Malleable Iron Co., Dayton, Ohio.

Max H. Sorensen . . . 65, owner of Sorensen Industries, Inc., Darby, Pa., manufacturer of castings, rings, and pump parts. He had served as national commander of Catholic War Veterans in 1946 and 1947.

T. W. Ballard, Sr., 57, founder of Idaho Falls Foundry, Idaho Falls, Idaho. After working in foundries in Utah, Nevada, and California, he formed his own business in 1932.

L. E. Emery, 38, chief metallurgist, Marion Malleable Iron Co., Marion, Ind.

L. E. Emery

He had been chief metallurgist for Lake City Malleable Iron Co., Ashtabula, Ohio, and plant metallurgist for Benton Harbor Malleable Industries, Benton Harbor, Mich., prior to 1951 when he joined Marion Malleable Iron Co. Emery was author of technical papers and active in AFS technical activities. He was a member of the Sand Division Materials Used in Malleable Foundries Committee.

W. C. Schartow, 50, plant manager, Chevrolet-Grey Iron Foundry, Saginaw, Mich., died from heart attack. He was a native of Saginaw. In 1928 he became a cooperative student at General Motors Institute, graduating in 1932. He advanced throughout the foundry serving in the laboratories, shops, and labor relations department, became personnel director of the foundry in 1947. He was promoted to production superintendent in 1951, general superintendent of production in 1952, and plant manager in 1956. He was active in AFS activities as well as civic affairs.

W. C. Schartow

Future Meetings and Exhibits

Nov. 27-Dec. 2 . . American Society of Mechanical Engineers, Annual Meeting. Statler Hotel, New York.

Nov. 30-Dec. 2 . . Metallurgical Society of AIME, Electric Furnace Conference. Morrison Hotel, Chicago.

Dec. 2 . . Malleable Founders Society, Semi-Annual Meeting. Sheraton-Cleveland Hotel, Cleveland.

Dec. 6-7 . . Foundry Facings Manufacturers Association, Annual Meeting. New York.

Dec. 6-8 . . National Association of Manufacturers, Annual Meeting. Waldorf-Astoria Hotel, New York.

Dec. 12-14 . . Material Handling Institute, Annual Meeting. Savoy-Hilton Hotel, New York.

1961

Feb. 9-10 . . AFS Wisconsin Regional Foundry Conference. Schroeder Hotel, Milwaukee.

Feb. 16-17 . . AFS Southeastern Regional Foundry Conference. Read House, Chattanooga, Tenn.

Feb. 26-March 2 . . American Institute of Mining, Metallurgical & Petroleum Engineers, Annual Meeting. Ambassador and Chase-Park Plaza Hotels, St. Louis.

March 1-2 . . Malleable Founders Society, Technical & Operating Conference. Wade Park Manor, Cleveland.

March 11-14 . . Steel Founders' Society of America, Annual Meeting. Drake Hotel, Chicago.

March 20-24 . . American Society for Metals, Western Metal Exposition & Congress, Pan-Pacific Auditorium, Los Angeles.

April 10-12 . . American Institute of Mining, Metallurgical & Petroleum Engineers, Open Hearth Steel Conference. Sheraton Hotel, Philadelphia.

April 18-20 . . Foundry Educational Foundation, Annual College-Industry Conference. Statler-Hilton Hotel, Cleveland.

April 18-20 . . American Welding Society, Annual Meeting and Welding Show. Commodore Hotel and Coliseum, New York.

May 8-12 . . AFS 65th Castings Congress & Exposition. Brooks Hall, Civic Auditorium, San Francisco.

May 10-12 . . National Industrial Sand Association, Annual Meeting. The Homestead, Hot Springs, Va.

June 8-9 . . Malleable Founders Society, Annual Meeting. The Broadmoor, Colorado Springs, Colo.

June 15-16 . . AFS Chapter Officers Conference. LaSalle Hotel, Chicago.

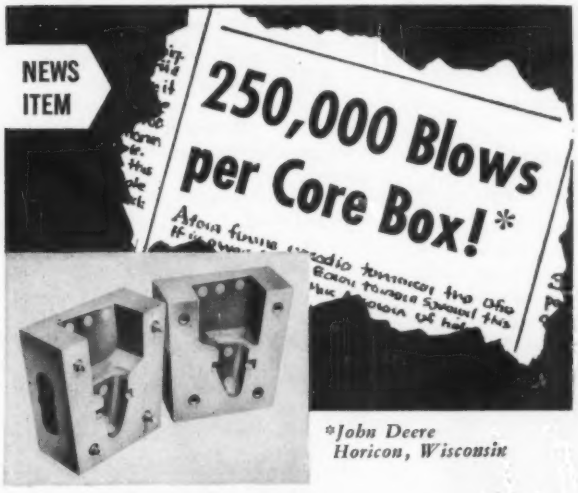
June 18-20 . . Alloy Casting Institute, Annual Meeting, Hot Springs, Va.

June 22-24 . . AFS Penn State Regional Foundry Conference. Penn State University, University Park, Pa.

June 25-30 . . American Society for Testing Materials, Annual Meeting. Chalfonte Haddon Hall, Atlantic City, N. J.

Sept. 24-26 . . Steel Founders' Society of America, Fall Meeting. The Homestead, Hot Springs, Va.

Oct. 18-20 . . Gray Iron Founders' Society, Annual Meeting. Royal York Hotel, Toronto, Ont.



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This Furane combination of Epocast 11B and Hardener 9812 makes a tough, long-wearing surface which withstands the abrasive action of blown sand. Another reason why Furane Epocast tooling plastics are finding widespread acceptance by foundries due to their versatility, economy and ease with which they fulfill difficult requirements.

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Circle No. 146, pages 157-158

Sand, grind, or polish metal, plastics and wood

"Oliver" No. 381 Heavy Duty, Oscillating Single Spindle Sander and Metal Grinder

Available with power tilting feature, operated by foot control. Dial at right indicates degree of tilt. The No. 381 is rigidly built to provide low cost operation, high efficiency. Rugged, it stands up under most adverse conditions.

OLIVER MACHINERY COMPANY
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Circle No. 147, pages 157-158

New Products and Processes

What's new in foundry methods and equipment? Summaries of many are presented below. Circle corresponding number on free postcard, page 157. Mail it to us; we'll do the rest!

Six-Foot Thermometers Provide Readings in Difficult Locations

Six-foot stainless steel thermometers allow measuring in stacks, ducts, ovens, and other normally inaccessible places. Available in temperature ranges of 0 to 200 F. and 200 to

1000 F., hand calibrated for accuracies within 1 per cent of the full scale reading. Large dials assure easy readings. W. C. Dillion & Co.

Circle No. 1, pages 157-158

Fork Lift Weighing Attachments Records Data While In-Transit

Fork lift electronic weighing attachment allows in-transit weighing of loads. Load is weighed as it is picked up and weight indicated on instrument panel. Can be installed on most of company's gas and electric models of 3000, 4000, and 5000-lb capacities. Clark Equipment Co.

Circle No. 2, pages 157-158

Liquid Improves Life, Efficiency of Polishing Belts and Disks

Liquid composition for abrasive polishing belts, disks, and wheels, greases, polishes, and cleans simultaneously. By reducing pressure needed to secure polishing action, use of composition reduces normal wear on abrasive surface, with savings. Automatically cleans the abrasive surface and maintains high cutting efficiency. Liquid applied to moving abrasive surfaces, loosens sand, dislodges impacted foreign material, lubricates abrasive surface. Myer & Ellis, Inc.

Circle No. 3, pages 157-158

New Low Iron Manganese Alloy Allows Economical Additions

A low iron manganese alloy for aluminum sand, permanent mold, and die castings has been added to company line. Composition consists of: Mn, 85-90; Fe, 2.0 max; Si, 3.0 max.; C, 6.0-7.0; P, 0.050 max. Vanadium Corp. of America.

Circle No. 4, pages 157-158

Expendable Thermocouple Features One-Piece Ceramic Cartridge

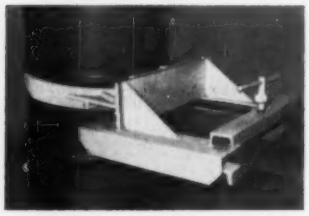
Expendable thermocouple for measuring steel bath temperatures is fully compensated. Tapered one-piece ceramic body of cartridge assures snug fit in protective paper sleeve, to eliminate metal leakage, and protect the holder from damage.

When operator connects themocouple, recorder lights green signal to indicate circuit is complete. As immersion is made, an amber light shows recorder is responding normally, after five seconds, a red light and audible signal informs operator that measurement is complete. Leeds & Northrup Co.

Circle No. 5, pages 157-158

Steel Drum Handler May Be Adapted to Forks or Aprons of Lift Trucks

Steel drum handler may be mounted on forks or aprons of any make or model of lift truck and most walkie



and straddle trucks. Arms automatically pick up drums in vertical position. Arms take up only a few more inches of space than drums making unit suited for narrow aisle stacking. Little Giant Products Co.

Circle No. 6, pages 157-158

Combination Core Knock-Out and Blast Unit Cuts Cleaning Time

Double elevator design with two abrasive cycling systems cuts cleaning time by using single machine to knock out cores and clean castings with one loading and unloading operation.

An innovation is a compensating separator which removes all sand from the abrasive operating mixtures even when sand loadings approach or equal the weight of the castings being processed. The entire operation is automatically controlled by a sequencing timer, permitting variable time settings for various phases of the operation.

Sequence of operations: for the core knock-out cycle:

1. Loading: Strip molds and load the machine with the cooled castings as with any standard blast machine. Most batch-type applications will use a skip bucket or tote box loader. Others will utilize the swing table or car table designs with this arrangement.

2. Core knock-out tumble: After the loader empties into the moving conveyor, the door closes. The castings tumble for a predetermined time allowing for some of the sand and cores to be knocked loose. During this period, sand is circulated through

the built-in by-pass abrasive system.

3. Core knock-out blast: The wheel is activated for a short period of time to knock out the remaining cores and heavy sand. This introduces a heavy surge of sand into the by-pass abrasive system. Sand not removed by the first pass through the separator is recirculated for further air washing.

4. Separation: As soon as the core knock-out blast is completed, the dipper valve at the wheel closes. The contaminated abrasive continues to recycle through the by-pass abrasive system for a pre-determined period of time.

Next, the blast cleaning cycle commences. Wheelabrator Corp.

Circle No. 7, pages 157-158

Portable Vacuum Equipment Slashes Cost of Removing Sand Spillage

Portable vacuum equipment cuts sand spillage pickup cost 83 per cent over hand-shovelling. Removal of sand from under sides and pan of conveyor formerly took 16-man hours

per week, all on weekends. Now one night-shift worker with vacuum equipment does same job in four hours. In addition, unit can be used for other cleaning duties in the plant. Vacuum Cleaner Mfg. Co.

Circle No. 8, pages 157-158

Special Rubber Outlasts Metals In Highly Abrasive Application

Urethane rubber, having hardness, resilience, and load bearing capacity with excellent resistance to abrasion, oxygen, ozone, oils, and grease, outperformed alloy steel plates in Chicago foundry application.

Each month the foundry blows 140,000 pounds of hot core sand through duct work leading to drying units. Rubber liner operated six months—five times that of mild steel and two and one-half times that of special alloy steel. Two to five shutdowns for repairs were saved in addition to the cost of welding steel plates to elbows. E. I. DuPont De-Nemours & Co.

Circle No. 9, pages 157-158

Automatic CO_2 Gassing Machines Eliminate Non-Productive Time

Automatic CO_2 gassing machines provide exact timing of gassing cycle, easy mechanical adjustment of gassing head to varying core box height. Table

height is easily adjustable to the level of core shooter table and existing roller conveyors. Gassing plate with CO_2 outlet clamps pneumatically against the core box. Automation through push-button control eliminates non-productive time found in manual operations. Roperwerk.

Circle No. 10, pages 157-158

Liquid Resin for Hot Core Box Technique Gives Instant Curing

Liquid resin permits instant curing. Average size cores can be stripped in 15 to 20 seconds after they are blown. Since curing reaction is primarily chemical and catalyst is activated by heated core box, the bench life of mixtures is four to six hours minimum.

Foundries equipped with blowers for oil-type cores need not invest heavily in equipment and floor space required to produce shell cores. Existing core blowers may be modified to accommodate the hot box technique. Existing mullers and core mixing equipment may be used without modification. Instantaneous heating of the mixture upon contact with core box reportedly produces a thorough deep cure into the center of the core. Archer-Daniels-Midland Co.

Circle No. 11, pages 157-158

Vocational Guidance Technique Matches Workers, Capabilities

Vocational guidance testing technique assists in fitting workers to jobs for which they are qualified. Takes about one hour to complete without supervision and six minutes to score.

Is suitable for all types of jobs and also serves as single test in measurements of aptitudes, rather than requiring separate tests for each of the 45 traits which comprise all occupations.

Unit consists of moveable slide card which is positioned to various sets of questions. Index permits ready reference and identification of 28 individual characteristics. In addition, a graphic picture of the family of related occupations to which these traits might belong. Personnel Research, Inc.

Circle No. 12, pages 157-158

Comparator Gives Determination of Grain Size in Copper Group

Micrographex comparator provides rapid determination of grain size in copper and copper base alloys. Features include external reflecting element to assure proper alignment of microscope and a 4x3-1/4 ground glass screen.

Grain size determined by mounting specimen on microscope stage, rotating standard micrographs which are turret-mounted on either side of viewing screen. Twelve A.S.T.M. standard micrographs represent sizes of 0.015 to 2.0 and identify a specimen as being between or the same as the standards. General Scientific Equipment Co.

Circle No. 13, pages 157-158

Portable Sand Conditioning Unit Features Unique Cooling Action

Portable sand conditioning unit handling up to 10 tons per hour, features cooling with combing construction. Sand is cooled and fluffed by churning action in the hopper;

the open discharge stream provides additional aeration and cooling. Low weight, detachable wheel barrow-type handles, and semi-pneumatic tires allow high degree of portability in job shops and side floors of larger operations. Royer Foundry & Machine Co.

Circle No. 14, pages 157-158

For The Asking

Build an idea file for improvement and profit.
Circle numbers on literature request card, page 157, for manufacturers' publications.

High intensity film viewer . . . for reading X-ray and Gamma Ray radiographs is described. Features, construction details, and operating method are highlighted. Princeton Div., Curtiss-Wright Corp.

Circle No. 49, pages 157-158

Briquettes . . . for gray iron castings are described, application and benefits are listed. Results are shown and the mechanical properties charted in 16-page brochure. Electro Minerals Div., Carborundum.

Circle No. 50, pages 157-158

Steel storage equipment . . . of many sizes and styles are shown in 8-page catalog #DC-60. Penco Div., Alan Wood Steel Co.

Circle No. 51, pages 157-158

Safety in lifting . . . is emphasized in brochure which gives specifications and working load limits for line of alloy chain slings, rings, links, and hooks. Wire Rope Div., Jones & Laughlin Steel Corp.

Circle No. 52, pages 157-158

Welding stainless steels . . . is 23-page manual reference guide which gives data on various stainless steels in use today, procedures for welding each, and types of electrodes and wires available. The McKay Co.

Circle No. 53, pages 157-158

Refractories . . . how they work for industry, and how refractories research contributes to technological progress are two topics covered in 16-page brochure. Harbison-Walker Refractories Co.

Circle No. 54, pages 157-158

Alloy iron properties . . . new bulletin charts the engineering properties of Meehanite metal, Ni-Resist iron, Ni-Resist Ductile iron and ductile iron. Mechanical and physical properties, and chemical composition are included in bulletin #158. Centrifugally Cast Products Div., The Shenango Furnace Co.

Circle No. 55, pages 157-158

Overhead handling . . . problem solvers are shown and described in new brochure. Also some 16 on-the-job case histories of modern lifting equipment are given. Manning, Maxwell & Moore.

Circle No. 56, pages 157-158

Flow rack . . . brochure presents photos, drawings and diagrams to explain principles, operation and installation of live storage method. The Rapids-Standard Co., Inc.

Circle No. 57, pages 157-158

Kold Kure Process . . . booklet gives technical data on synthetic binder for making cores, mold, core boxes and patterns. G. E. Smith, Inc.

Circle No. 58, pages 157-158

Sand reclamation—bulletin 2000 illustrates and describes features of Pneu-Reclaim integrated and package systems. Beardsley and Piper.

Circle No. 59, pages 157-158

Green shell carb—product sheet lists features of the product which is identified as a blend of carbons. Data is available. American Colloid Co.

Circle No. 60, pages 157-158

Thermocouple components . . . are featured in 28-page catalog. Bare elements, elements with insulators, insulators, metal and ceramic protecting tubes, heads, blocks, connectors, and miscellaneous fittings are described and detailed specifications given. Minneapolis-Honeywell Regulator Co.

Circle No. 61, pages 157-158

CO_2 process core shooting and gassing machines . . . technical data sheet on these special purpose machines includes information on shoot heads, air filters and spray lubricators, plus detailed specifications. Roperwerk.

Circle No. 62, pages 157-158

Metalcasting technology . . . experts have written many books and manuals which are available through AFS. A complete, classified list is yours when you use the circle number below. American Foundrymen's Society.

Circle No. 63, pages 157-158

Manganese steels . . . Technical paper on some metallurgical factors influence austenitic manganese steels. American Foundrymens' Society.

Circle No. 64, pages 157-158

Shaw process . . . Patterns Principles and production are discussed in technical paper. American Foundrymens' Society.

Circle No. 65, pages 157-158

High stress abrasion . . . Factors influencing the resistance of steel castings to high stress abrasion are discussed in Castings Congress Paper. American Foundrymens' Society.

Circle No. 66, pages 157-158

Sand design . . . A progress report on the systematic approach to sand design and control is presented in current technical paper. American Foundrymens' Society.

Circle No. 67, pages 157-158

Adjustable storage rack . . . Brochure emphasizes simplicity of the two-part upright frame and shelf beam assembly. Palmer-Shile Co.

Circle No. 68, pages 157-158

Foundry core binders . . . baked strength product is described in combination with core oils. Also, brochure explains how core oil can be added to the binder in varying proportions relative to core size and geometry to regulate drying speed and prevent overbake of small cores. Charts show green compression, sag resistance, overhand strength and bakeability of cores. Corn Products Sales Co.

Circle No. 69, pages 157-158

Flame hardening . . . brochure, 12 pages, illustrates various problems and their solutions. Equipment discussed ranges from standard torches and tips to specialized machines. Air Reduction Sales Co.

Circle No. 70, pages 157-158

Conveyor engineering . . . brochure outlines possibilities for improving production through electrical and

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Washes, Core & Mold	141
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gravity conveyors, electronics, and hydraulic and pneumatic devices. Cites case of automation in foundry, handling 18,000-lb units. Logan Conveyors Co.

Circle No. 71, pages 157-158

X-ray units . . . are detailed and shown in bulletin. Specifications for four models are given and various features and uses pointed up. Princeton Div., Curtiss-Wright Corp.

Circle No. 72, pages 157-158

Deoxidizer . . . bulletin describes Ferrocarbo deoxidizer for addition to malleable iron. Refines white iron structure, speeds first stage annealing, improves fluidity, raises mechanical properties, betters machinability, controls oxidation, and reduces scrap. The Carborundum Co.

Circle No. 73, pages 157-158

Safety glass . . . brochure illustrates various models and complete range of bridge and eye sizes, with and without face shields. American Optical Co.

Circle No. 74, pages 157-158

Magnetic particle inspection . . . bulletin covers various processes and equipment used to inspect steel castings, extra costs and facilities available. Lebanon Steel Foundry Co.

Circle No. 75, pages 157-158

Automatic heat processing . . . equipment bulletin, 16 pages, describes machines for heat treating, selective hardening, brazing and soldering, annealing, and other metals heating processes. Cites typical applications. Selas Corp. of America.

Circle No. 76, pages 157-158

Core shooting, gassing machines . . . automatic turntable models are described in 4-page bulletin. Diagrams, technical data and general information are included. Roperwerk.

Circle No. 77, pages 157-158

Compressed air filters . . . new operating principle for removing dirt, oil, and water is described; maximum flow rates are charted, and specifications given. King Engineering Corp.

Circle No. 78, pages 157-158

Air-setting periclase ramming mixes . . . literature defines various types, chemical analysis, and installation data. Used for electric furnaces and ladles for maintenance or new construction. H. K. Porter Co.

Circle No. 79, pages 157-158

Mold handling systems . . . for large, medium and small size molds are described, and illustrated in 12-page booklet. Diagrams are given, and continuous or intermittent operation units are shown. The C. O. Bartlett & Snow Co.

Circle No. 80, pages 157-158

Welding, brazing, and soldering alloy . . . and flux catalog (56 pages) is pocket size and helpful for design, production and maintenance engineers and foremen. All-State Welding Alloys Co.

Circle No. 81, pages 157-158

Aluminum oxide castables . . . Data sheets (8 pages) on 33-1 and 33-HD gives properties, characteristics, applications and preparation methods. Refractories Division, Norton Co.

Circle No. 82, pages 157-158

Sand measurements . . . Sand Angularity and shape factors is discussed, pointing up the surface area measurements and theoretical and experimental relationship. American Foundrymens' Society.

Circle No. 83, pages 157-158

Diffusion coatings . . . advanced process in metallurgy that gives parts a surface layer to resist oxidation is described in 4-page brochure. Mechanical properties are charted plus a description of parts that can be coated. Haynes Stellite Co.

Circle No. 84, pages 157-158

Roof exhausters . . . vertical-discharge, roof-mounted types, feature leakproof, unified aluminum structure for light weight and easy maintenance. Four-page bulletin details specifications, ratings, and dimensions. Iron Lung Mfg. Co.

Circle No. 85, pages 157-158

Industrial truck selection . . . simplified by eight-page brochure which includes seven tips for choosing the right truck, five areas of misapplication, case histories, and application pictures for various models. Automatic Transportation Co.

Circle No. 86, pages 157-158

Power tool program . . . for higher production from portable power tools consists of 28-page report and slide rule. Guidebook offers basic formulas for computing dividend on payroll dollars possible by planned annual retooling. Work space provided for computations. Slide rule gives rapid calculation for gross dividend on payroll dollars. Ingersoll-Rand.

Circle No. 87, pages 157-158

Hardness testing equipment . . . catalog contains information on the principle of the Rockwell hardness test, microhardness testing and illustrates models for specific uses. Included are fully automatic models, motorized models for elevated temperature testing, internal hardness testing, mobile tester and diamond penetrators with various accessories. Wilson Mechanical Instrument Div., American Chain & Cable Co.

Circle No. 88, pages 157-158

High temperature alloy . . . comparative chart shows company's complete line in 20-page booklet. Seventeen leading alloys are compared against each other in the areas of physical, mechanical and chemical properties and stress-rupture data. Charts show selected properties for each alloy at specific temperatures and recommendations for either investment casting or shell and resin shell mold castings. Haynes Stellite Co., Div. Union Carbide Corp.

Circle No. 89, pages 157-158

Select eye and face protection . . . for wide variety of industrial applications with forty-page catalog. Includes vision testing equipment, goggles, faceshields, welding helmets, and accessories and parts. Mine Safety Appliance Co.

Circle No. 90, pages 157-158

Heat treating stainless steel . . . technical research report, deals with castable hardenable types suitable for investment casting. Covers straight martensitic stainless, precipitation hardenable martensitic stainless, and semi-austenitic precipitation hardenable stainless. Concentrates on conditions and problems peculiar to investment castings and transformation behavior and the effects of chemistry of these alloys. Test bar results are also presented. WaiMet Alloys Co., Div. Howe Sound Co.

Circle No. 91, pages 157-158

Casting Quality Chart Reprints Available

Requests for the recently-published, 2-color, Casting Quality Chart are pouring in. So much so that we have had the chart reprinted and are able to start filling requests.

Readers, who have not yet asked for a copy . . . suitable for mounting on the wall . . . still have time to do so while the supply lasts. Orders will be filled on a first-come, first-served basis. The first copy is **free.** Additional copies are available at 25¢ each.

Circle No. 120, pages 157-158

Classified Advertising

For Sale, Help Wanted, Personals, Engineering Service, etc., set solid . . 35c per word, 30 words minimum, prepaid.
Positions Wanted . . 10c per word, 30 words minimum, prepaid. Box number, care of **Modern Castings,** counts as 10 words.
Display Classified . . Based on per column width, per inch . . 1-time, $22.00 6-time, $20.00 per insertion; 12-time, $18.00 per insertion; prepaid.

HELP WANTED

FOUNDRY METALLURGIST
$10,000 to $12,000
and
JR. FOUNDRY METALLURGIST
$7,200 to $8,400
Both positions offer advancement and are with companies well respected. Clients assume the expenses. Contact Paul Sheldon
MONARCH PERSONNEL
28 East Jackson Blvd. Chicago 4, Illinois

PLANT ENGINEERS
Experienced on layout of all types of foundry equipment, material handling and material flows. Send complete details on work history, education and family status. Include recent photograph. All replies confidential. **Box F-140, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

GOOD FOUNDRYMEN
when you need **SUPERVISORY** or **TECHNICAL** men why not consult a man with actual foundry experience plus 15 years in finding and placing **FOUNDRY PERSONNEL.**
Or if you are a **FOUNDRYMAN** looking for a new position you will want the advantages of this experience and close contact with employers throughout the country.
For action contact: John Cope
DRAKE PERSONNEL, INC.
29 E. Madison St., Chicago 2, Illinois
Financial 6-8700

SUPERINTENDENT
MALLEABLE FOUNDRY
Fully qualified superintendent for large foundry producing malleable fittings and automotive and agricultural implement castings at the rate of 1,000 tons per month. Preferred age 35-45. Send full details on experience, education and family status. All replies will be held in confidence. **Box L-104, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

ABRASIVES
Experienced shot and grit service man. Contact foundries, steel mills, metal-working plants. Salary and commission.
Box L-102, MODERN CASTINGS
Golf & Wolf Roads Des Plaines, Ill.

MAINTENANCE GENERAL FOREMAN to head plant maintenance department in a leading eastern steel foundry. Should have at least five years experience in foundry or steel mill field and be well versed in modern day maintenance management techniques. Mechanical or electrical engineering graduate preferred but will consider others of proper qualifications. Position is one of real challenge, offers optimum opportunity and pays well. Send detail resume to **Box K-103, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

INDUSTRIAL ENGINEER—Exceptional opportunity for graduate industrial engineer with a minimum of 3 years experience capable of developing, maintaining and supervising a job cost system for the control of labor and process costs. Midwest Steel Foundry. Excellent working conditions. Salary commensurate with experience and background. Please furnish a complete resume of experience and education. All replies will be treated confidential. **Box L-107, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

POSITIONS WANTED

CORE ROOM SUPERINTENDENT . . . Twenty-six years experience in Gray Iron Foundry; eighteen years on supervision. Age 48; married. Qualified to take complete charge of all core room operations. All types of cores. Making, finishing and assembling cores. Willing to relocate. **Box L-100, MODERN CASTINGS, Golf and Wolf Roads. Des Plaines, Ill.**

SUPERINTENDENT OR GENERAL FOREMAN—Thirty years experience in jobbing and production from ounces to thirty tons. Good practical knowledge of moulding, coremaking, cleaning, cupola operations, sand control; also a fair knowledge of metallurgy. Age 46, married. **Box L-103, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

PLANT ENGINEER—19 years top experience in all phases Methods, Plant Layout, Construction, Plant Engineering, Maintenance, Automation and Material Handling. Aggressive, personable individual seeking a strong challenge in sales or engineering. Domestic or foreign assignment acceptable. **Box L-101, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRY EXECUTIVE, SALES OR MANUFACTURING—Young man, Engineering Graduate, sixteen years in steel foundry manufacturing and sales. Experienced in alloy steel, stainless, 17-4 PH, AM 355, monels, ductile iron, and ni-resist castings. Qualified in aircraft and missile quality castings. Knowledge of aircraft and atomic energy specifications, magnaflux, dye penetrant, and radiographic standards. Now employed. **Box L-108, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

FOUNDRYMAN with experience in all metals including magnetic alloys and in pattern engineering seeks position in continental U.S.A. **Box L-109, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

SALESMAN EXPERIENCED GRAY IRON FOUNDRY looking for connection with good gray iron foundry. My sales totalled $350,000 last year. **Reply Box L-105, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.**

ENGINEERING SERVICES

FOUNDRY CONSULTANT — NON-FERROUS Sand casting — permanent mold casting — centrifugal casting — in aluminum — brasses — bronzes — 30% leaded bronze — aircraft quality bearings and castings — ED JENKINS, West Palm Beach, Florida — PHONE: Temple 2-8685.

FOR SALE

ONE MODEL 3 UNIT DRIVE SIMPSON MULLER—with Bucket Loader, Double Discharge Hoppers, Mill Belt, Bucket Elevator, National System Aerator, 14-ft. long Prepared Sand Conveyor, 50 ton Sand Storage Bin. All in good condition. Address Box H-110, MODERN CASTINGS, Golf and Wolf Roads, Des Plaines, Ill.

QUALITY EQUIPMENT
SAVE AT LEAST 50%
MELTING & HEAT TREAT UNITS
BLAST CLEANING
MOLDING MACHINES
SAND CONDITIONING
Your largest dealer for all foundry equip't.
UNIVERSAL Mach'y & Equip't Co.
Box 873, Reading, Pa. FRanklin 3-5103

Honor Steel Foundries In Safety Contest

Sixty-three steel foundries recently were honored for outstanding safety records by the Steel Founders' Society of America. This year 129 foundries entered the annual contest and reported an accident rate of 14.1, a rate bettered only in 1958 when it was 12.9.

Thirty-nine foundries received awards for perfect safety records for the three-month period, June through August; 24 received awards for cumulative accident frequency rates of less than 10.

The awards were presented during their three-day technical and operating conference. Nearly 500 foundrymen from Canada and the United States attended. Papers were presented on cores and core binders, welding and hardfacing, ladles and pouring practice, process and control, and risering of steel castings.

New Books for You . . .

Small Plant Management: A Guide to Practical, Know-How Management . . . W. A. MacCrehan, Jr., 560 pages. American Society of Mechanical Engineers, 327 W. 41st St., New York. Second Edition. 1960. Management techniques especially suited for application in small plants or technical service units are treated in newly published edition. Describes and illustrates new concepts, and improved procedures of planning, organizing, and supervising. Provides information on such aspects as small plants as economic units, management tasks, solving important problems of small management, and the future of the small plant. Among topics are financing and banking, organizing the plant, principles of scientific management, government interest in small plants, sales planning and forecasting, and quality control. Information provided on how to fulfill legal requirements, do technical research, and how to obtain best sales.

How to Communicate Policies and Instructions . . . Joseph D. Cooper, 352 pages, Bureau of National Affairs, Inc., 1231 24th Ave. N.W., Washington 7, D. C. Covers all types of instructions on such matters as policy, technical, sales, consumer "how to do it" or "how to use it," purchasing, and training. Provides a variety of examples with checklists and practical tips on language and use of illustrations, including photography, artwork, and exhibits. One chapter devoted to how to write and explain, including how to aim at the reader, covering the subject, preparing the outline, writing style and technique, rules for clarity and brevity, and proper choice of words.

Franklin Metal Research Reports . . . Franklin Institute Laboratories for Research and Development, 20th and Franklin Parkway, Philadelphia 3. A syllabus of reports on metal research available to corporate management and research executives. Studies reprinted cover a wide range of subjects including purification of highly reactive metals; fine particle ferromagnetism; kinetics of recovery; recrystallization and grain growth; plastic deformation of metals and alloys; diffusion in solids; and thermoelectricity. Heavy emphasis is placed on zone refining of metals. Address request on corporate letterhead.

Encyclopedia of Science and Technology . . . 15 volumes, McGraw-Hill Book Co., 330 W. 42d St., New York 36. Contains more than six million words approximately 10,000 illustrations, and 7200 articles. Covers fields of life science, physical science, earth science, and engineering. Written within comprehension of college underclassman and layman interested in science and engineering.

National Fire Codes . . . National Fire Protection Association, 60 Batterymarch, Boston 10, 5614 pages. 1960. Seven-volume compilation contains the 181 standards developed by N.F.P.A. in the fields of flammable liquids and gases, combustible solids, dusts, chemicals and explosives; building construction and equipment; extinguishing equipment; electrical installations; mobile fire equipment; and transportation and management. New materials consists of 42 new or revised fire safety standards adopted at the 1960 meeting of the association and incorporates all amendments approved by the N.F.P.A. board of directors up to and including July, 1960. Although purely advisory, the standards and codes are widely used in the United States, Canada, and abroad as the basis for governmental regulations and a guide for good practice in industry and commerce.

Bearing Group Adds Educational Program

An educational program to be developed with engineering schools and additional research will be undertaken by the Cast Bronze Bearing Institute, a product group of the Non-Ferrous Founders' Society.

Research on hydrostatic lubrication of bearings will be carried on at Franklin Institute, Philadelphia.

Officers elected are: President, Carter N. Paden, Jr., Moccasin Bushing Co., Chattanooga, Tenn.; Vice-President, A. G. Eberle, Renewal Service, Inc., Philadelphia; and Secretary-Treasurer, Raymond O. Oyler, Bunting Brass & Bronze Co., Toledo, Ohio.

Elected Directors for a three-year term are: Oyler, John Mitchell, Markey Bronze Bushing Co., Delta, Ohio; and immediate past president, W. H. Crossman, Randall Graphite Bearings, Inc., Lima, Ohio.

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The Editor's Forum . . .

Are you wondering . . . what the safely dressed foundryman wears these days? I couldn't help but be impressed as I looked over the array of safety clothing on exhibit at the National Safety Council Annual Exposition. Years ago—and not too many at that—safety clothing looked ugly and was as uncomfortable as a medieval suit of armor. Now the well-dressed and safe-dressed foundry worker wears—a bright colored light weight plastic helmet with built-in sweat band . . . prescription ground safety goggles with color and style of rims to suit his taste . . . a comfortable aluminized rayon jacket to reflect heat. . . flame proofed trousers that shed sparks like a duck sheds water . . . and safety shoes in any style to match the season or personal preference—you could wear them to church or to a dance and no one would know they had steel toes. It's not hard to get workers to wear protective clothing when it is comfortable and looks neat. Don't miss reading the complete report on the new look in safety, page 123, this issue.

Controlled cooling of ductile iron . . . brings another variable under control in the constant struggle to make hi-fi castings. In visiting with Eric Welander, metallurgist at John Deere Malleable Iron Works, East Moline, Ill., I observed this customized care in daily practice. Eric explained to me that "controlled cooling" is heat treating in the mold for a definite period of time in order to achieve proper as-cast hardness. Optimum time interval between pouring and shakeout are determined for each type of casting and recorded on the job ticket. As soon as casting is poured the time for shakeout is written on a blackboard located at end of pour-off line. When mold-soaking period is over, castings are dumped into shakeout system for air-cooling. With this kind of control, consistent physicals are obtained in ductile iron castings without resorting to expensive heat treatment.

A major scientific break-through . . . is what Dr. Eugene Wainer, Horizons Inc., calls a unique metallurgical process combining ceramic fibers with metal to attain almost unbelievable strengths —500,000 psi. He writes: "One of the most promising combos is a blend of 80 per cent nickel —20 per cent chromium alloy with aluminum oxide fibers of sapphire or corundum single-crystal form". All the production problems have not yet been ironed-out but the process will probably lend itself to casting. It wasn't so long ago that 300,000 psi steel castings seemed like fantasia. But now they are a reality. So with the accelerated pace of technology the 500,000 psi metal-ceramic fiber casting may be closer than you think.

Have any of you foundrymen . . . been concerned about touching off an explosion in large pit molds when first molten metal enters the mold? It's rumored that this can be serious and that such molds should be flushed with CO_2 gas before pouring. If any of you have this problem, please let me know how you handle it.

More about Sulfinuz process . . . a number of readers asked me for more information about the Sulfinuz treatment mentioned several months ago in "Around the World with Modern Castings." So here goes: Extraordinary resistance to scuffing and wear resistance can be conferred on ferrous metals by immersion in a special salt bath at 500-600 C. Nitrogen and sulphur diffuse from the bath into surface of metal. Treated steel has replaced bronze clutch plates and bearing cages and is finding wide use for ejector pins and all other moving parts of die casting dies. Other Sulfinized parts include wire drawing blocks, drop forging slides, nuts, bolts, cylinder liners, tappets, and gears. If you are interested in the name of the company in England controlling the process just drop me a letter requesting it.

Jack H. Schaum

VOLCLAY BENTONITE

NEWS LETTER No. 71

REPORTING NEWS AND DEVELOPMENTS IN THE FOUNDRY USE OF BENTONITE

"INSUFFICIENT MULLING"

Shorter mulling is responsible for many casting defects and scrap. Whether fast mullers of 90 second cycles, or slow mullers of 5 minute cycles, **each loses efficiency by reducing mulling time.**

SHORTER MULLING PRODUCES:—

1. **Brittle sands.**
2. **Hotter sands that are more difficult to cool.**
3. **Less green compression strength.**
4. **Waste of bond, or additives.**
5. **Loss of control.**
6. **Variable molding properties which lead to irregular mixtures.**
7. **Increased cleaning of castings.**
8. **Increased scrap.**

BOND MUST BE MULLED into the molding sand to become effective.

As mulling time is shortened, the bond is not properly mixed—it is poorly dispersed.

Temper water migrates toward the bond and clay balls may result which are soaked with excess added water.

Molders are quick to detect insufficiently mulled sands. Production declines when molders are not satisfied.

The savings in scrap is not tangible, but scrap is higher where shorter mulling exists.

Since this problem is recognized, why is it ignored?

DO YOU HAVE NL-23?

"What Did We Do Before Mullers Were Used"?

AMERICAN COLLOID COMPANY

SKOKIE, ILLINOIS • ***Producers of Volclay and Panther Creek Bentonite***

Pouring a 2000-lb. casting at ELECTRIC BOAT DIVISION, GENERAL DYNAMICS CORPORATION, Groton, Conn.
The U.S.S. GEORGE WASHINGTON, America's first POLARIS-firing A-sub

RCI Core Binders

Used in precision castings for America's A-Subs

• Precision castings are critical pieces in ELECTRIC BOAT'S gigantic A-sub production puzzle. Every phase of the project is tightly security-sealed. While it is no secret that a variety of A-sub valves, structural boxes, gear cases and other components, are poured — in aluminum-bronze, manganese-bronze, super-nickel and other metals — specifics are unavailable. One thing's for sure: castings must be perfect! And, it is reported that in operations where ELECTRIC BOAT is using RCI Core Binders, they find that excellent results are obtained.

If you have a core binding problem, chances are RCI has already found the answer. Liquid phenolic, liquid amino and liquid oleoresinous core binding resins, liquid sand conditioners, liquid binders (self-curing), and liquid phenolic, powdered phenolic and granulated phenolic resins for shell coremaking and shell molding are all on the list of RCI Foundry Products. Let's talk about Reichhold resins in terms of *your* applications.

FOUNDREZ — *Synthetic Resin Binders*
COROVIT — *Self-Curing Binders*
coRCIment — *Core Oils*
CO-RELEES — *Sand Conditioning Agent*
REICOTE — *Sand Coating Agent*

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